UNITED STATES ATOMIC ENERGY COMMISSION

Annual Report to Congress

OF THE

ATOMIC ENERGY COMMISSION

FOR

1961

January 1962

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C.

LETTER OF SUBMITTAL

WASHINGTON, D.C.,
30 January 1962.

SIRS: We have the honor to submit herewith the Annual Report of United States Atomic Energy Commission for 1961 as required the Atomic Energy Act of 1954.

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION,
JOHN S. GRAHAM.
LELAND J. HAWORTH.
LOREN K. OLSON.
ROBERT E. WILSON.
GLENN T. SEABORG, *Chairman.*

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The President of the Senate.
Honorable
The Speaker of the House of Representatives.

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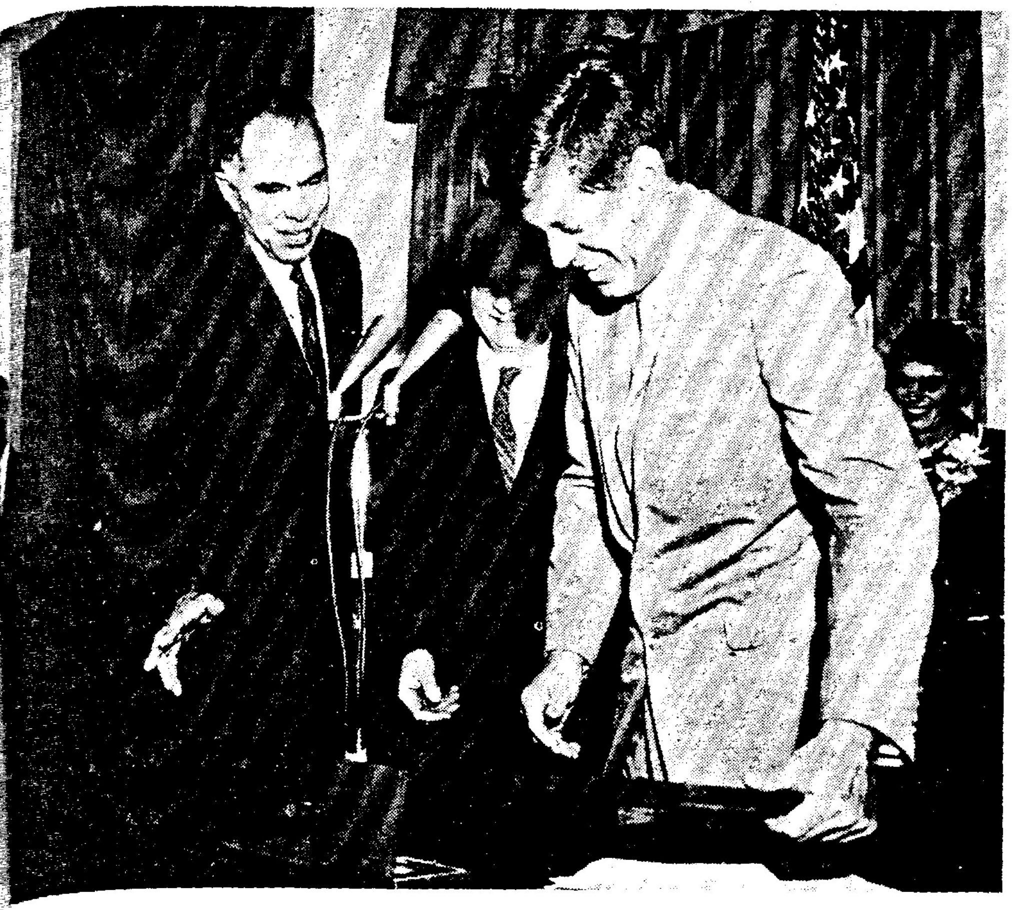

...ward *Presentation.* The 1961 recipient of the Commission's prized ... Fermi Award was Dr. Hans A. Bethe, internationally known nuclear ...eoretical physicist and Professor of Physics at Cornell University. The ... consisted of a gold medal, a citation, and $50,000. Photo shows Dr. ... (center) about to receive the gold medal and check from President ...dy during a White House ceremony on December 1 as Commission Chair-... Glenn T. Seaborg looks on. In part, the citation read ". . . . in recogni-... of his outstanding contributions in the fields of nuclear and theoretical ... which helped to establish the foundations of nuclear physics and nuclear ...ogy; in the applications of atomic energy for the betterment of mankind; ...pons technology; and as a teacher and a leader of men." Dr. Bethe was ... n Strasbourg, Alsace-Lorraine on July 2, 1906. During the early 1930's ...ied under Lord Rutherford at Cambridge University and Dr. Fermi in ... and in 1935 he came to the United States to teach at Cornell. His early ... n nuclear physics included contributions to the theory of nuclear reac-... which formed the basis for the development of atomic energy during ... War II. During the war, Dr. Bethe worked on the atomic weapons ... at Los Alamos Scientific Laboratory. Since the war, he has made ... important contributions in nuclear theory and participated in technical ... directed toward the use of nuclear energy for the production of useful ... The Fermi Award was established in 1956 in the name of the leader ... group of scientists who successfully operated, in Chicago on December 2, ... e world's first nuclear reactor, proving that a nuclear fission chain ... could be self sustained and controlled. The recipients are named on ... of meritorious contributions to the development, use, or control of ...ergy. Previously, the Award has been made to Dr. John von Neumann, ... Ernest O. Lawrence, 1957; Dr. Eugene P. Wigner, 1958; and Dr. Sea-... There was no award made in 1960.

MILITARY APPLICATION

The Commission's program of developing nuclear energy for mili-
... applications and related work during 1961 included:

The first U.S. nuclear weapons test in two years and 11 months ... place underground at the Nevada Test Site on September 15, ... this nation's voluntary suspension of tests. By year's end, ... underground tests at the site had been announced.

Two new research and test reactor facilities were put into operation ... aid in studying radiation effects on materials and components and obtaining basic physics and chemistry information necessary for ...pons development.

Preliminary work for a series of nuclear and high explosive detona- ... was undertaken in programs being carried out jointly with the ...rtment of Defense to effect a capability of detecting and identify- ... nuclear detonations.

WEAPONS DEVELOPMENT AND PRODUCTION

...pons Development

During the latter part of 1961, an accelerated effort was applied ... weapons development at each of the three weapons laboratories, ... is, Sandia Corp., Los Alamos, and Livermore. Also during 1961, ...ding on a broad base of general research in each of the labora- ...es, new weapons designs were produced to meet specific Depart- ...t of Defense weapons system requirements. Improvements in ...n were also directed at better reliability, greater safety, and in- ...ed effectiveness per pound of warhead weight. A considerable ...t was also directed to a study of the comparison of weapons de- ...pment possible without testing, as compared to what could be ...plished either limited to underground testing only or to testing ... any environment without limitation. New effort was also applied ... design of weapons diagnostic instrumentation that would permit ...ter flexibility in the choice of method of weapons testing.

...pons Tests

... September 1, 1961, the Soviets abruptly and cynically broke the ...torium on nuclear testing by launching an extensive and varied

nuclear test series of about 50 atmospheric detonations with a total yield of about 120 megatons. This series obviously had required extensive preparations during the negotiations for a test ban. Shortly thereafter, on September 15, 1961, the United States initiated a weapons test program underground at the Commission's Nevada Test Site. By the end of the year, the Commission had announced eight nuclear weapons tests, all of low yield, and all conducted underground.

Underground testing is limited to the lower yield devices (up to some tens of kilotons at present) and certain types of tests, particularly some effects tests, cannot be made in this way at all. Hence, steps were taken to prepare for a series of tests in the atmosphere in the event the President should decide to expand the test effort in this way.

While important development information with respect to nuclear weapons design was discovered in the course of the underground tests, these tests also revealed that testing underground is a slower and more expensive process than had previously been assumed. It has proved to be more difficult to diagnose some of the results of development tests; operational difficulties such as post-shot re-entry and re-use of partially contaminated tunnels were continuing factors in delaying the test program.[1] The Commission and its contractors are vigorously attacking these problems and marked progress is being made.

Weapons Production

Under Presidential authorization, the production of nuclear weapons by the Atomic Energy Commission continued in 1961. The production effort was responsive to Department of Defense requirements such as providing warheads for new weapons systems, and for bombs that would permit a greater flexibility in methods of delivery. The new weapons produced during 1961 were of considerably more modern design with improved effectiveness, reliability and safety over weapons previously in the stockpile. The program for retirement of obsolescent weapons was also continued.

Weapons Facilities

Construction began in November on a $3.5 million specialized plant at Oak Ridge, Tenn., to meet weapons production requirements.

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[1] The necessity of limiting the exposures of tunnel workers to radiation required the re-assignment of some workmen to areas at NTS where no radioactivity is present. The highest exposure to any tunnel worker was approximately 8 rem for the calendar year 1961. In no case did an individual's exposure carry him above the lifetime formula 5 (N–18) rem where N is the age of the individual at his next birthday. This formula has been recommended by the Federal Radiation Council and approved in 1960 by the President as protection guidance for radiation workers.

The Lawrence Radiation Laboratory acquired a STRETCH 7030 computer in October. A similar computer had been delivered to Los Alamos Scientific Laboratory earlier in the year. These computers will increase the capacity of the laboratories to solve problems requiring speed and large memory storage.

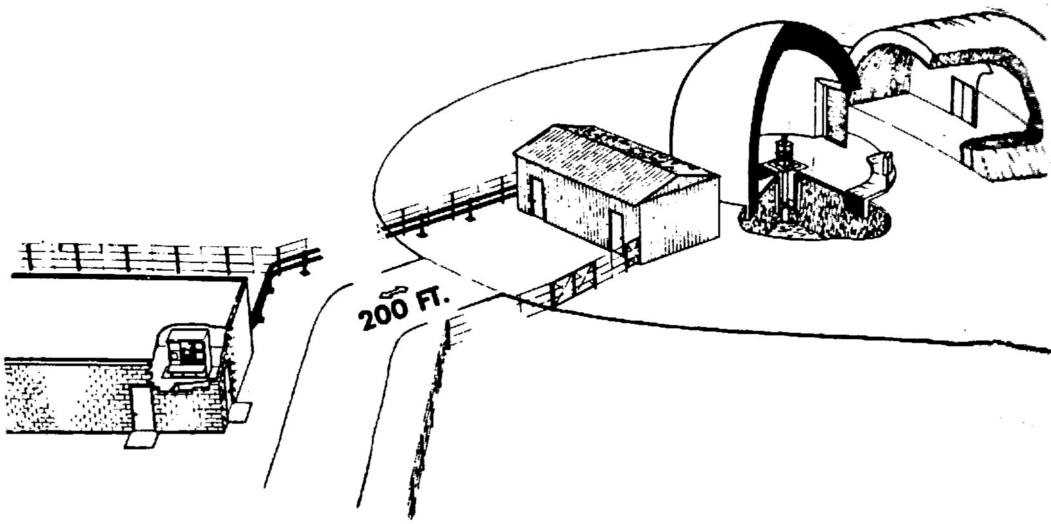
The Commission's water-impact test activities at the Salton Sea Base ceased during the year and disposal of facilities will be made through the General Services Administration. Future water entry testing of inert (non-nuclear) weapons shapes will be conducted at other Government installations. The Salton Sea Base had been established in 1941 as a Navy facility for torpedo and skip bombing practice. It was taken over by the Commission in 1947.

Radiation Environment Facilities

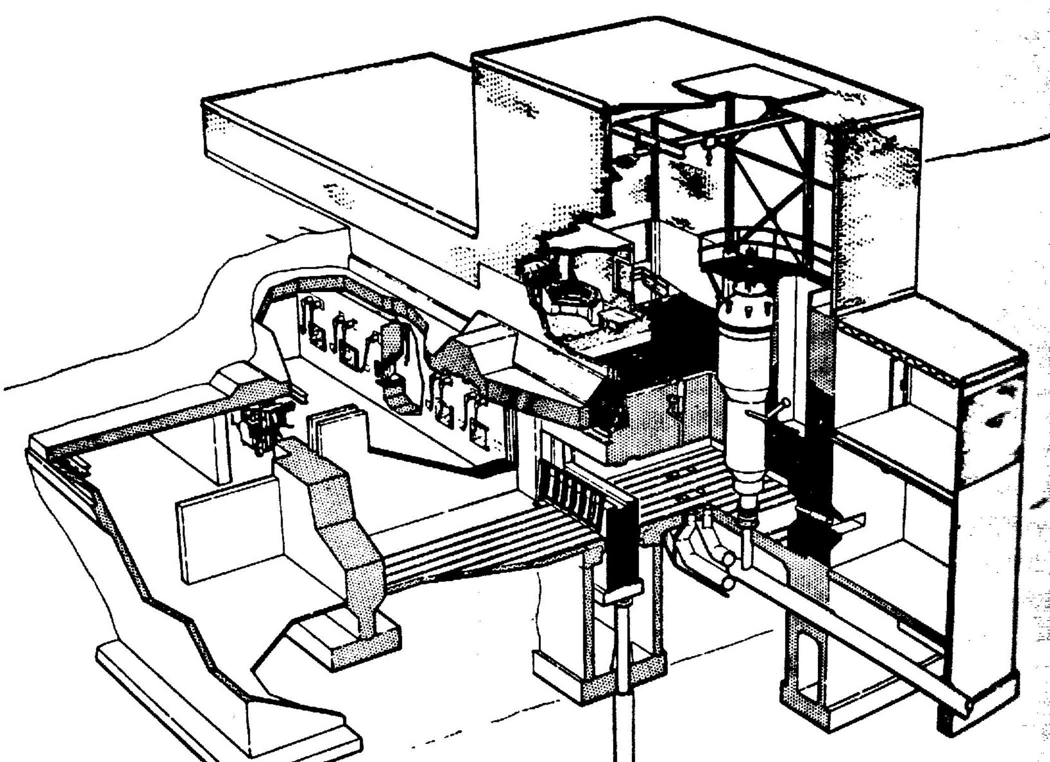
Two new facilities for study of the effects of radiation environments on material and components have been installed at Sandia Laboratory. In the past, the Van de Graaff Accelerator facility and radioactive sources have been used. The new facilities, the Sandia Pulsed Reactor Facility (SPRF), and the Sandia Engineering Reactor Facility (SERF), will be used to extend and accelerate studies in the basic physics and chemistry of neutrons and gamma ray bombardment phenomena. They will similarly extend and accelerate engineering studies of the radiation tolerance of materials, components, and electronic circuits.

The Sandia Pulsed Reactor makes it possible to study the response of materials, components, and electronic circuits to transient radiation fields. Associated with the SPRF is a pulsed X-ray device which may be used to segregate the effects due to high-energy electromagnetic radiation from those caused by a combined neutron and gamma ray bombardment. The SPRF facility will also be extensively used in studies conducted for Department of Defense agencies and their contractors.

The SERF is designed for carrying out a variety of radiation effects studies. In this facility, large components can be irradiated in combination with other environments such as high or low temperature, vacuum, or shock. The facility includes two cryostats for use in fundamental studies of neutron bombardment phenomena at very low temperatures. It is extremely flexible in that other experimental devices may be installed with relative ease. In addition,



New Sandia Reactors. Two new facilities have been added at the Commission's Sandia Corp. laboratories in New Mexico that will be used to extend and to accelerate studies in the basic physics and chemistry of neutrons and gamma ray bombardment phenomena. Drawing *above* shows the Sandia Pulse Reactor Facility (SPRF) which will be used to study the response of materials and electronic circuits to transient radiation fields. The control room (left) will be located several hundred feet from the reactor (under half-dome) to protect personnel from the massive pulses of radiation. Drawing *below* shows the major parts of the Sandia Engineering Reactor facility (SERF) which will be used in radiation effects studies on large components under varying environments.



provides laboratory space and the most advanced remote handling ...ipment system for use in post-irradiation analysis.

These two reactor facilities not only extend the Laboratory's re...rch and experimental capacities in military programs but may also ...d application in civilian research.

DETECTION OF NUCLEAR EXPLOSIONS

Studies continued on ways and means to improve detection tech...ues and systems, both for underground and space applications.

The Commission is participating in the *VELA* program, which is ...rdinated by the Department of Defense, to improve the capability ... detecting and identifying nuclear detonations for the purpose of ...eloping an adequate system capable of monitoring a nuclear test ... treaty.

...la-*Uniform Program*

The purpose of the *Vela-Uniform* Program is the development of ...hniques for improving the capability of detecting and identifying ...derground nuclear explosions. The Commission is involved pri...arily in making available large seismic signal sources for the tech...al measurements to be obtained. In this connection it is responsi... for over-all program coordination; emplacement and detonation ... all nuclear devices; yield and limited technical measurements; ...blic safety, and any on-site logistical and construction support serv...es required by the technical agencies involved.

With the resumption of nuclear weapons development tests, Vela-...iform measurements are being made on underground detonations. ... addition to data obtained from the late 1961 weapons tests, valuable ...ormation was obtained from the December 10 Project Gnome ex...riment of the Plowshare program.

The Commission's Office of Field Operations (formerly Office of ... Operations) has performed an exploratory program at the Ta...a Salt Dome in Mississippi to verify its suitability for use in the ...ibble series. Project Dribble would consist of a series of nuclear ...osions to be conducted in a salt dome to provide information on ...oupling (i.e., use of a large underground cavity as an explosion ... to reduce the seismic signals generated) and data comparison with ...derground nuclear detonations in other media. Programs are being ...anced to assure public safety of the planned nuclear detonations. Because of the priority of the weapons tests program, scheduling ... the Dribble series is in abeyance. Data obtained from the seismic

measurements made on weapons tests detonations at the Nevada Test Site will have an effect on the final planning for this program.

Vela-Hotel Program

The Commission, through its Sandia Laboratory, the Los Alamos Scientific Laboratory, and Lawrence Radiation Laboratory (Livermore)[2] is participating in the Department of Defense *Vela-Hotel* Program, a research and development effort aimed at developing satellite-based instruments and systems to detect nuclear explosions in space.

The current program now calls for five *Atlas Agena* launchings in 1963–1964, each to put two instrumented satellites into earth orbits. In addition, instrumentation will be included on a variety of other space vehicles to measure background radiation at various levels above the earth.

The program of developing instrumentation for satellites for the Atlas Agena launchings is a cooperative effort by Los Alamos Scientific Laboratory and Sandia Laboratory. Radiation detectors for neutrons, gamma rays and X-rays will be employed. The Lawrence Radiation Laboratory (Livermore) has participated in the background measurement program. As part of this work, instrumentation has been flown on several Discoverer vehicles with special emphasis on measurement of X-ray bursts.

Vela-Sierra Program

The Los Alamos Scientific Laboratory is participating in the Department of Defense *Vela-Sierra* program to develop ground-based instruments for possible detection of nuclear explosions in space. An experimental detector station using air fluorescence as a signal was designed, fabricated, and field tested in Greenland. This system is based on the detection of the fluorescence of nitrogen when bombarded by X-rays. Design criteria for an operational station were also completed during the year, and an experimental direct-optical detection station was built and is being tested. This method utilizes an optical system to measure the visible light produced by a nuclear detonation.

[2] The Lawrence Radiation Laboratory, which is contract-operated for the Commission by the University of California has facilities at Livermore, Calif., as well as on the University's Berkeley campus. The Livermore facilities are primarily concerned with research and development on matters associated with nuclear explosives, and research on thermonuclear (fusion) reactors. While some thermonuclear work is also done at the Berkeley facilities, most of the effort at this site is in the life sciences, physics, and chemistry fundamental research areas. Throughout this report, Berkeley or Livermore is parenthesized to indicate at which of the Lawrence Radiation Laboratory sites the work mentioned is being done.

al Defense Agreements

changes of information under Agreements for Cooperation with nations for mutual defense purposes, reported in the Annual rt to Congress for 1960,[3] continued during 1961. The United -United Kingdom Agreement for Cooperation, which is con-ably broader than other agreements, involves the exchange of ied information on nuclear weapons and the exchange of visits en scientists of the two countries.

United States has mutual defense agreements in effect with alia, Canada, France, the Federal Republic of Germany, Greece, Netherlands, Turkey, Italy, the United Kingdom, and the North tic Treaty Organization (NATO). (The effective dates of these ments are shown in Table 4 of the International Activities sec-of this report.)

RAW MATERIALS

ring 1961, the Commission continued to renegotiate and extend mestic concentrate purchase arrangements in accordance with ly announced programs. Of the total quantity of uranium esti-d to be purchased after July 1, 1961, under the announced domes-grams, approximately 90 percent is now included in new mill cts and contract extensions extending beyond March 31, 1962, n most cases to December 31, 1966. In order to obtain a more m rate of delivery, some contract extensions involved the de- until later years of uranium scheduled for delivery prior to The year's highlights for the Commission's raw materials m include:

Uranium concentrate deliveries totaled 30,325 tons of uranium (U_3O_8) of which domestic sources accounted for 57 percent; s from Canada accounted for 29 percent of the total concen-received, and overseas receipts, 14 percent.

At the year end, the Commission had 25 domestic contracts for ocurement of uranium from 27 mills, one of which is nearing tion in the Shirley Basin Area of Wyoming. Nineteen of the tracts extend through 1966, three have earlier termination dates e of limited supplies of eligible ore and three contract exten-are in the process of negotiation. The mill at Lakeview, Oreg., ded operations during 1960 for lack of ore.

One new processing mill, the first in Texas, began operations the year.

[3] p. 125.

- Production of uranium from Florida phosphates was terminated during the year after operations showed the feasibility of this source as a reserve for the future.
- Uranium miners were granted an exemption from the need to be licensed to transfer uranium ore from mine to mill, or to buying stations.
- Recent exploration discoveries, along the Idaho-Montana border, of large veins of the mineral thorite, may give the United States a thorium reserve of 100,000 tons. There is a possibility that several times this quantity may eventually be developed.
- The joint United States-United Kingdom Combined Development Agency contract for purchase of South African uranium was replaced by two separate contracts. The new AEC-South Africa contract provides for a reduction in price and a minor deferral of deliveries.

Domestic Activities

Procurement Record

Over the past ten years, the Commission's procurement of uranium concentrate has shifted from a heavy dependence upon foreign suppliers to a situation where domestic producers currently supply 55 percent of the total receipts of U_3O_8. The table below shows the procurement on a *fiscal year* basis.

Table 1.—PROCUREMENT RECORD FOR URANIUM CONCENTRATES

Fiscal years	Domestic: Tons U_3O_8	Domestic: Percent of total	Canada: Tons U_3O_8	Canada: Percent of total	Overseas: Tons U_3O_8	Overseas: Percent of total	Total tons U_3O_8
1952	830	23	210	6	2,620	71	[illegible]
1953	990	34	225	8	1,685	58	[illegible]
1954	1,450	31	690	15	2,550	54	[illegible]
1955	2,140	36	830	14	2,970	50	[illegible]
1956	4,200	40	1,590	15	4,650	45	[illegible]
1957	7,580	47	3,370	21	5,210	32	[illegible]
1958	10,245	39	9,475	36	6,655	25	[illegible]
1959	15,160	45	13,505	41	4,660	14	[illegible]
1960	16,565	48	13,445	39	4,570	13	[illegible]
1961	17,760	55	10,250	32	4,250	13	[illegible]
Totals	76,920	45	53,590	32	39,820	23	[illegible]

Projected Uranium Receipts

Projections of uranium concentrate deliveries from domestic, Canadian, and overseas sources under existing commitments for the period July 1, 1961, through December 31, 1966, show that there will be a drop from approximately 30,000 tons of U_3O_8 received in fiscal year 1962, to about 18,000 tons in fiscal year 1966. In this latter period, receipts from overseas sources will be about 1,600 tons and Canadian deliveries will have been reduced to about 500 tons.

The forecast, as shown in the following chart, is based upon contracts and allocations assigned, or to be assigned, to domestic mining properties. No short-falls in foreign deliveries are anticipated, barring major economic or political disturbances. A large percentage of domestic deliveries is equally firm. However, a considerable number of production allocations are assigned to properties which may prove marginal or submarginal. Consequently, total projected domestic deliveries may fall short several thousand tons as a result of failure to produce the full amount covered by allocations and milling contracts. Delivery short-falls have occurred in the past as a result of delays in bringing mines into full production, lower grade ore than anticipated, failure of ore supply, or milling problems.

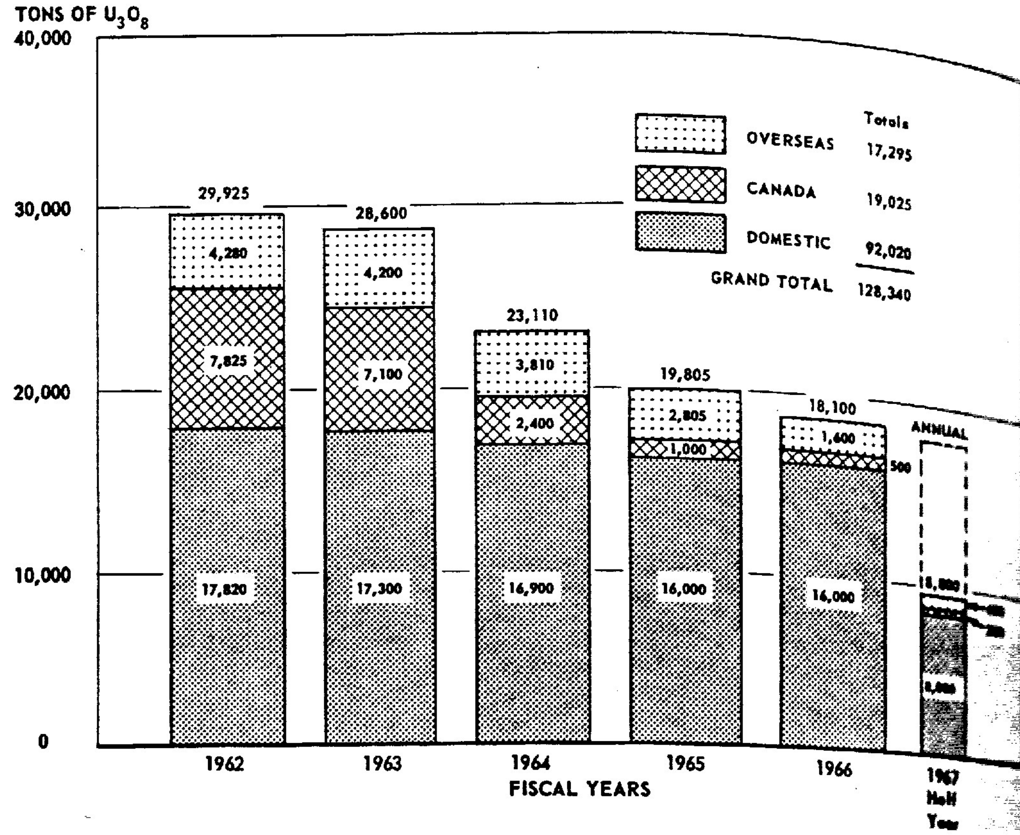
Domestic production, which is estimated at 17,820 tons in fiscal year 1962, will decline to about 16,000 tons per year by 1965 and remain at this level through 1966. Foreign procurement, however, will drop rapidly after fiscal year 1963 and will be only 2,100 tons in fiscal year 1966. Under the present projected commitments, for the period July 1, 1961, through December 31, 1966, the domestic uranium producers will supply approximately 72 percent of the total uranium purchases.

Uranium Production

Uranium ore production in the United States totaled approximately 8 million dry tons during 1961, as compared to 8.0 million tons in the previous 12 months. Receipts of uranium oxide (U_3O_8) in concentrates for the year totaled 17,410 tons.

Domestic ore reserves at the end of 1961 were reduced to 74 million tons as compared with 82 million tons reported at the end of 1960. In addition, 1.3 million tons of ore were in Government and private stockpiles. The reduction in ore reserves reflects the mining of approximately 8 million tons during 1961. Ore reserve estimates are being reviewed in the light of new information which has been developed in the course of mining.

PROJECTED URANIUM RECEIPTS



Production Allocations

The domestic uranium concentrate procurement program for the period March 31, 1962–December 31, 1966, was limited by the Commission's announcement of November 24, 1958,[4] to the purchase of appropriate quantities of uranium in concentrates derived from ore reserves developed as of the date of the announcement. Mill contracts and contract extensions negotiated pursuant to the November 24, 1958, announcement provide that ore processed in the mill for the production of uranium concentrate for sale to the Commission shall be obtained only from properties and in amounts covered by Commission allocations.

In developing the program established November 24, 1958, the Commission recognized that a large number of mining properties contain irregular deposits which, under normal procedures, are not developed far in advance of mining. Most of the small, independent mining operations, as well as a few larger ones, fall in this category. For this type of operation, the Commission announced in February that it will consider using the historical production rate of a mining property, rather than developed ore reserves, as a basis for establish-

[4] See pp. 113–115, Annual Report to Congress (January–December 1960); pp. [illegible] Annual Report to Congress (January–December 1959).

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a market. A large number of small mining properties would lify under this announcement. Where a historical production s is used, the allocation will relate to ore production over the od July 1, 1956, through June 30, 1960.

llocations covering purchases from most of the larger mining perties have been established and have been incorporated in milling racts.

mall, independently owned mining properties will represent a e percentage of the total number of allocations, but ore reserves ch properties constitute a relatively small proportion of the total. tically all of the active producing properties have been examined the Commission and allocations have been calculated. Ore pur- contracts between producers and mills for the 1962–1966 period be approved by the Commission to determine that the quantities e delivered and processed are in accordance with established ations.

d *Uranium Mine.* **Aerial photo shows the Frazier-Lamac uranium open** e of Western Nuclear, Inc. **The mine is located in the central Gas Hills** Wyoming. **It is the largest stripping operation in the Gas Hills area** the peak of operations, **more than 2,200,000 cubic yards of overburden** moved in one month. (Photo courtesy of **Riverton Ranger, Riverton,**

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Milling Operations

During 1961, the Commission modified and extended six more contracts with ore processing mills to provide an appropriate market in the 1962–1966 period for uranium concentrates produced from reserves developed prior to November 24, 1958. The Petrotomics Co. is building a new mill in Shirley Basin, Carbon County, Wyo., to produce concentrates in the post-1962 period under the November 24, 1958, announcement. The mill, which is expected to be able to treat up to 400 tons of ore a day, is scheduled for completion March 31, 1962.

Of the 25 milling contracts, 19 extend through 1966 and three terminate before 1966 by reason of a limited eligible ore supply. The three remaining contracts due to expire March 31, 1962, which are in the process of negotiation for extension, are:

Company	*Location*	*Capacity in tons of ore per day*
Mines Development, Inc	Edgemont, S. Dak	[illegible]
Rare Metals Corp. of America	Tuba City, Ariz	[illegible]
Vitro Chemical Co	Salt Lake City, Utah	[illegible]

Additional Milling Facilities

On April 2, 1958,[5] the Commission announced a limited expansion of domestic uranium procurement to provide an additional market for ore reserves developed prior to November 1, 1957. The contracting for additional mill capacities under this program in those areas having either no market or an inadequate market was completed during 1960 with the exception of the lignite area of North Dakota-South Dakota for which there is still no ore milling facility. The terms of a contract with International Resources Corp. involving construction of a mill in Bowman, N. Dak., to treat uraniferous lignite were agreed upon by the Commission in October 1960. However, the contract was not executed because of failure of the contractor to arrange financing.

The new 200 ton-per-day uranium mill of Susquehanna-Western, Inc., located near Falls City, Texas, started operations in April. This is the first uranium milling operation in Texas, and will draw on ore reserves developed prior to November 1958, principally in Karnes and Duval Counties.

A list of uranium processing mills as of December 31, 1961, is given in Table 2 on page 177.

[5] See pp. 115–117, Annual Report to Congress (January–December 1960).

...nium from Florida Phosphates

...e Commission's contract with U.S. Phosphoric Products Divi... Tennessee Corp., for the production of uranium from Florida ...phates expired in June and final shipment of uranium was made ...July. The operation of the company's plant at East Tampa was ...ssful and demonstrated that uranium can be produced as a by...duct in the manufacture of triple superphosphate fertilizer at ...nable cost. These operations showed that, should a market de...p in the future, byproduct uranium could be produced from ...ida phosphates at a direct cost, exclusive of plant costs, of $8.00 ...s per pound of U_3O_8. There is a production potential of about ... tons U_3O_8 per year from current phosphate operations.

...ium Miners Exempted from AEC Licensing Regulations

...e Commission's source material licensing regulations (Title 10, ... of Federal Regulations, Part 40) were revised early in the year. ...r the revised regulations, uranium miners are no longer required ...ave a Commission license to transfer uranium ores from mine to ... or to a buying station. Under regulations in effect since 1947, ...ium miners were required to have a Commission license to transfer ...fined and unprocessed ores containing source material after it was ...d. A license still will be required to refine or process uranium ... including the mechanical upgrading of ores.

...active Hazards in Uranium Mills and Mines

...nium ore processing mills are Commission-licensed operations ...t to Commission regulatory control, including Title 10, Code of ...al Regulations, Part 20, "Standards for Protection Against ...ation." The physical control of concentrations of uranium dust ...e mill atmosphere, and also of concentrations of radioactive ...tuents in liquid effluents from the mills, requires continual sur...nce in order to comply with established standards. When neces... the Commission has ordered a mill operator to take steps to ... situations that could be a hazard to the health and safety of ...yees or the public.

...e radioactive hazards of uranium mines are subject to control ... the provisions of State regulations. The Commission assists

the State agencies and the Federal agencies concerned with this problem in carrying out environmental surveys and in developing procedures to control the air contamination level in the mines. Commission representatives are also assisting the working group of the Federal Radiation Council in a study of the radiation hazards in uranium mining.

Public Sale of Vanadium Pentoxide

In January, bids were opened on 1.5 million pounds (750 tons) of vanadium pentoxide (V_2O_5) which were offered for sale by the Commission's Grand Junction Office. Successful bidders on 570 tons of the V_2O_5 concentrates were Union Carbide Metals Co. (424 tons), Vanadium Corp. of America (98 tons), and Derby and Co. (48 tons). The average price per pound for the 570 tons amounted to $1.011; the total bid was $1,152,756.60. A bid price of $0.91 per pound was rejected on four lots containing 180 tons of V_2O_5.

The Vanadium Corp. of America was the successful bidder in a previous sale (May 1960) for more than 1.5 million pounds (790 tons) of vanadium pentoxide, at $1.00 per pound V_2O_5.

Vanadium pentoxide is a co-product recovered in the processing of uranium-vanadium ores. The amounts received by the Commission were the result of early contracts under which the Commission agreed to purchase the vanadium when production was in excess of current commercial requirements. This provision was intended to encourage the production of uranium from the treatment of uranium-vanadium bearing ores. Vanadium pentoxide is used principally as an alloying material in steel and as a catalytic agent in the chemical industry.

Thorium Reserves

Recent private exploration in the Lemhi Pass area of Idaho and Montana has revealed the existence of a number of large and persistent veins carrying a relatively high thorium content in the form of thorite. Although drilling and underground development have not been extensive, the large persistent veins have been exposed at frequent intervals for distances of up to 3,000 feet and at elevations ranging from 5,000 to 8,000 feet. Samples indicate a large tonnage of ore averaging in excess of one-half percent ThO_2. On the basis

geological information and the limited amount of sampling, it ars that these deposits may contain approximately 100,000 tons ThO_2 in ore which would be commercial at current prices. Furmore, the persistence of mineralization in the veins on which exploration has been carried out, and the existence of a large ber of additional but unexplored veins, offer possibility for the ntual development of a reserve several times this figure.

Prior to the Lemhi Pass development, no important thorium de-ts had been found in the United States. Reserves had been esti-d at 20,000 tons of ThO_2 with possibilities of an additional 30,000 . These figures related primarily to small deposits or relatively grade deposits of monazite from which it was estimated the cost ecovery might be approximately \$10.00 per pound ThO_2 in refined , as compared with the current market of \$4.50 to \$5.50 per nd.

he current industrial uses for thorium are rather limited. Poten-y, it is an important source of fuel for nuclear power. The mission has no procurement program for thorium as the small k on hand is sufficient to cover its projected requirements for rch and development.

Foreign Activities

liveries of foreign uranium concentrates to the United States g 1961 totaled 12,915 tons of contained U_3O_8 with 8,735 tons g from Canada, 3,870 tons from South Africa, and 310 tons the Combined Development Agency contracts with Australia Portugal.

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adian deliveries, which were about 11,310 tons of contained in 1960, totaled 8,735 tons in 1961. The reduction is a result stretch-out agreement made in November 1959 between the ission and Canada.[6] Further decreases in deliveries are ex-d in ensuing years. At December 31, 1961, approximately 15,200 of Canadian uranium remained to be delivered.

p. 61-62, Annual Report to Congress (January–December 1959).

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South Africa

Following discussions by Combined Development Agency (CDA) representatives in Johannesburg during February and November of 1960, agreement was reached with the South African Atomic Energy Board, effective January 1, 1961, to terminate the CDA uranium purchase arrangement and replace it with separate United States-South Africa and United Kingdom-South Africa contracts.

Under the new contract, the United States will purchase 18,900 tons of U_3O_8 between January 1, 1961, and December 31, 1966—the same quantity the Commission would have bought under the CDA agreement, but at a lower price. A small quantity of South African material originally scheduled for delivery in 1961 and 1962 will be delivered in the post-1962 period but, as in the case of the superseded CDA agreement, all deliveries to the United States will be completed by December 31, 1966.

Australia and Portugal

The CDA agreement for production from Radium Hill, South Australia, expired on December 31, 1961, while the agreement for production from Rum Jungle, Australia, will expire in January 1963. Deliveries from Portugal should be completed about mid-1962. Total remaining deliveries to the Commission from Australia and Portugal after December 31, 1961, will be approximataly 200 tons of U_3O_8.

[7] A contracting agency established in 1944 as a joint United States-United Kingdom operation to insure cooperation in securing urgently needed supplies of uranium for the wartime atomic energy programs. It has continued to act on behalf of the United States and the United Kingdom with respect to the purchase of uranium ores and concentrates from non-domestic sources. Canada also is a member of the organization but, as a uranium producer with limited requirements, it has not participated in the joint United States-United Kingdom procurement activities.

Company	Location of mill	First contract signed	First U_3O_8 delivered to AEC	Present contract terminates	Rated capacity tons of ore per day	Estimated cost of mill
1. American Metal Climax, Inc.[a]	Grand Junction, Colo.	July 10, 1950	June 1951	Dec. 31, 1966	330	$3,038,000
2. Anaconda Co.	Grants, N. Mex.	Dec. 27, 1951	Sept. 1953	Dec. 31, 1965	3,000	19,358,000
3. Cotter Corp.	Canon City, Colo.	May 23, 1957	Aug. 1958	Feb. 28, 1965	200	1,800,000
4. Dawn Mining Co.	Ford, Wash.	Aug. 8, 1956	Sept. 1957	Dec. 31, 1966	400	3,100,000
5. Fed.-Radorock-Gas Hills Partners	Fremont County, Wyo.	Apr. 10, 1959	Dec. 1959	Dec. 31, 1966	520	3,370,000
6. Globe Mining Co.	Natrona County, Wyo.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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Company	Location of mill	First contract signed	First U_3O_8 delivered to AEC	Present contract terminates	Capacity tons of ore per day	Estimated cost of mill
1. American Metal Climax, Inc.[a]	Grand Junction, Colo.	July 10, 1950	June 1951	Dec. 31, 1966	330	$3,038,000
2. Anaconda Co.	Grants, N. Mex.	Dec. 27, 1951	Sept. 1953	Dec. 31, 1966	3,000	19,358,000
3. Cotter Corp.	Canon City, Colo.	May 23, 1957	Aug. 1958	Feb. 28, 1965	200	1,800,000
4. Dawn Mining Co.	Ford, Wash.	Aug. 8, 1956	Sept. 1957	Dec. 31, 1966	400	3,100,000
5. Fed.-Radorock-Gas Hills Partners	Fremont County, Wyo.	Apr. 10, 1959	Dec. 1959	Dec. 31, 1966	520	3,370,000
6. Globe Mining Co.	Natrona County, Wyo.	May 12, 1959	Feb. 1960	Dec. 31, 1966	490	3,100,000
7. Gunnison Mining Co.	Gunnison, Colo.	Nov. 15, 1956	Feb. 1958	Dec. 31, 1966	200	2,025,000
8. Homestake-Sapin Partners	Grants, N. Mex.	Apr. 23, 1957	Sept. 1958	Dec. 31, 1966	1,500	9,000,000
9. Homestake-Sapin Partners	Grants, N. Mex.[b]	Dec. 20, 1956	Apr. 1958	Dec. 31, 1966	750	5,325,000
10. Kermac Nuclear Fuels Corp	Grants, N. Mex.	May 3, 1957	Dec. 1958	Dec. 31, 1966	3,300	16,000,000
11. Kerr-McGee Oil Industries	Shiprock, N. Mex.	Aug. 17, 1953	Jan. 1955	Dec. 31, 1966	300	3,161,000
12. Lakeview Mining Co.	Lakeview, Oreg.	Nov. 18, 1957	Feb. 1959	Nov. 30, 1963	210	2,600,000
13. Mines Development, Inc.	Edgemont, S. Dak.	Apr. 28, 1955	Aug. 1956	Mar. 31, 1962	400	1,900,000
14. Petrotomics Co.	Carbon County, Wyo.[c]	Aug. 12, 1960	----------	Dec. 31, 1966	200	1,500,000
15. Phillips Petroleum Co.	Grants, N. Mex.	Sept. 17, 1957	Aug. 1958	Dec. 31, 1966	1,725	9,500,000
16. Rare Metals Corp. of America	Tuba City, Ariz.	July 15, 1955	July 1956	Mar. 31, 1962	300	3,600,000
17. Susquehanna-Western, Inc.	Riverton, Wyo.	Dec. 4, 1957	Jan. 1959	Dec. 31, 1966	500	3,500,000
18. Susquehanna-Western, Inc.	Falls City, Tex.	July 25, 1960	June 1961	Dec. 31, 1966	200	2,000,000
19. Texas-Zinc Minerals Corp	Mexican Hat, Utah	July 17, 1956	Nov. 1957	Dec. 31, 1966	1,000	7,000,000
20. Trace Elements Co.	Maybell, Colo.	Aug. 10, 1955	Dec. 1957	Dec. 31, 1966	300	2,208,000
21. Union Carbide Nuclear Co.	Rifle, Colo.[d]	Oct. 2, 1947	Dec. 1947	Dec. 31, 1966	1,000	8,500,000
22. Union Carbide Nuclear Co.	Uravan, Colo.[d]	Apr. 13, 1949	Mar. 1950	Dec. 31, 1966	1,000	5,000,000
23. Uranium Reduction Co.	Moab, Utah	June 1, 1955	Nov. 1956	Dec. 31, 1966	1,500	11,172,000
24. Utah Const. & Mining Co.	Fremont County, Wyo.	Nov. 14, 1956	Mar. 1958	Dec. 31, 1966	980	6,900,000
25. Vanadium Corp. of America	Durango, Colo.	Feb. 17, 1949	Aug. 1949	Dec. 31, 1966	750	813,000
26. Vitro Chemical Co.	Salt Lake City, Utah	Oct. 25, 1951	Oct. 1951	Mar. 31, 1962	600	5,500,000
27. Western Nuclear, Inc.	Jeffrey City, Wyo.	Aug. 10, 1956	Aug. 1957	Dec. 31, 1966	845	4,300,000
TOTALS					22,500	145,320,000

[a] Formerly Climax Uranium Co.

[b] Formerly owned by Homestake-New Mexico Partners and acquired by Homestake-Sapin Partners in November 1961.

[c] Under construction.

[d] New contract agreement, signed in May 1961, replaced separate contracts for these two mills.

NOTE.—The above mills are privately owned and operated, and all are licensed to buy uranium ores from producers. The U.S. Atomic Energy Commission buys the concentrate product under the terms of contracts with each mill operator.

PRODUCTION

In the calendar year 1961, source and special nuclear materials as well as other production materials such as tritium and heavy water continued to be produced in quantities in compliance with Presidential Directives (or as required to satisfy military and peaceful needs). Reductions in unit operating costs were achieved in many areas through increased operating efficiency, and a high safety record was compiled at each production site.

Highlights of the Commission's production operations as they relate to the civilian program during calendar year 1961 include:

- A total of 800 kilocuries of purified strontium 90 was recovered from fission product wastes at Hanford, primarily for use in the SNAP (Systems for Nuclear Auxiliary Power) program.
- Two pre-1950 facilities which have been maintained on a standby basis are being reactivated at Hanford for use in recovery of strontium 90, cesium 137, and cerium 144 as the requirements for use of these radioisotopes increase.
- Reconsideration of a 1959 decision resulted in the designation of only the Savannah River and Idaho facilities as sites for receiving and chemically processing spent fuel from privately owned and other non-Commission reactors; the first three contracts for such services were signed.
- Some 74,000 cubic feet of radioactive waste materials were received from licensees for burial at Commission-owned sites; Commission activities generated an additional 3.2 million cubic feet of waste for burial.
- A series of meetings was held between Commission and United Kingdom Atomic Energy Authority personnel to exchange information on production problems and procedures.

Fission Product Production Program

The greatly increased requirement for strontium 90 and cesium 137 radioisotopes for use in Government programs has led to the recovery of these fission products from the chemical processing waste stream at the Hanford Plant, Wash. The strontium 90 is being used primarily in the Commission's SNAP program (see Nuclear Power for Space section of Part 2) and the cesium 137 is being used for fabrication into heat-energy sources and for radiation sources for a variety of applications (see Radioisotope and Radiation Development section of Part 2).

To meet the increased demand, two facilities built at Hanford prior 1950 have been reactivated and improved processes developed for recovery of strontium 90, cesium 137, cerium 144, and promethium

During the year, about 780 kilocuries of crude strontium 90 were re-ered from the Purex head-end process. Of this amount, 70 kilo-ies were further purified by ion exchange in the high-level radio-mistry cells and then shipped to Oak Ridge National Laboratory, n., for encapsulation. Approximately 710 kilocuries of strontium were further purified by solvent extraction techniques using the Hot niworks Facility which had been built in 1948 to serve as a semi-ks plant for the Redox Chemical Separations System. Later, be-e being placed on a standby basis, the facility had been remodeled use with the Purex Chemical Separations System.

In addition to the strontium 90 production, 210 kilocuries of cesium were recovered from Hanford's waste tank supernatant by absorp-on Decalso (an inorganic ion exchange medium) and shipped to Ridge for isotopes development program needs.

Modifications are also being made in Hanford's standby "B-Can-"—one of the three fuel element processing plants built during rtime for plutonium recovery—to handle and store crude fission duct concentrates containing multi-megacurie amounts of stron-n and promethium for decay of objectionable short-lived radioiso-es. These crude concentrates are produced in the Purex plant d-end by treating the Purex waste (raffinate) stream and are then mped to B-Canyon for further concentration and storage.

-Production Fuel Processing

In order to carry out the program of making financial settlement leased material being returned in the form of irradiated reactor the Commission had made an announcement in October 1959, its facilities at Hanford, Oak Ridge, Savannah River, S.C., and Idaho Chemical Processing Plant were prepared to negotiate con-ts to provide for chemical processing and settlement of specific ear fuel elements which had been irradiated in privately and licly owned reactors. After further study, responsibilities for re-ing all the irradiated fuels from research, test, power, and pro-ion reactors, and for the design of plant modifications to permit essing these fuels, were assigned only to the Idaho and Savannah r plants. Idaho is responsible for the receipt of all highly en-d uranium fuels, and Savannah River is responsible for all other production fuels. A public announcement to this effect was made

in June 1961, by the Idaho and Savannah River Operations Offices. The reassignment was made to reduce the over-all costs and still retain sufficient capability in Commission facilities to handle the returned non-production fuel elements and meet Commission program needs.

Three contracts were executed at Idaho during 1961 for receipt of non-production reactor fuels and for settlement of the contained fuel values in accordance with existing announcements.[8] Two of these contracts are with General Electric for fuels from its Vallecitos Boiling Water Reactor and test reactor, respectively, and the other is with Westinghouse for its test reactor fuel. Although no contracts have been executed for receipt of fuels at Savannah River, negotiations between that office and several power reactor operators are currently underway.

At Savannah River, a facility for handling and storage of non-production fuels was started in June 1961. It is expected to be completed about January 1963. The plant modifications to process non-production fuels at Savannah River have not been initiated.

Disposition of Facilities

Demolition, building decontamination, and site restoration at the Destrehan Street plant in St. Louis, Mo., have been completed. As of November 30, the site and facilities were returned to the Mallinckrodt Chemical Works, thus ending Commission activity at this location.

Efforts to sell the Government-owned magnesium plant at Canaan, Conn., have been unsuccessful, as have the efforts to purchase satisfactory magnesium from commercial sources. As a result, the General Services Administration (GSA) has extended the Commission's permit to use the Canaan plant until mid-1962. The plant will continue to be operated, under contract, by the New England Lime Co.

Arrangements have been completed for the transfer of extrusion equipment from the plant at Adrian, Mich., to the Bridgeport Brass Co. plant at Ashtabula, Ohio. The action involves disposition of two Commission-owned extrusion presses and auxiliary equipment at the Adrian plant, prior to turning over the space to the purchaser of the plant from GSA. The schedule called for terminating all operations at Adrian by the end of September. One press was shut down on September 1 for dismantling, shipping, and reinstallation at Ashtabula. The other continued in operation through most of September and was sold by competitive bid on September 29. It will remain at Adrian.

[8] Published in the *Federal Register* (F.R. 1591) of December 12, 1957.

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ial in Idaho. Low-level, packaged radioactive wastes collected from Com-ssion and licensee facilities in the western half of the country are buried on reservation of the National Reactor Testing Station in Idaho. Photo shows stes encased in concrete within steel drums, which were originally destined deep-sea disposal, being buried at the Idaho site. The wastes had been ected and prepared for sea disposal by a Southern California waste disposal which had its license revoked by the Commission during early 1961. The mission subsequently had the wastes transported to Idaho for land burial.

d Burial of Radioactive Wastes

Commission policy provides for permanent land-burial of low-level ckaged radioactive wastes generated in privately owned operations Government-owned land (Federal or State) to assure adequate tection of public health and safety throughout the period of any ential hazard.

Commission burial grounds located at Savannah River, Idaho, Han-d, Oak Ridge, Los Alamos and Sandia, N. Mex., the Nevada Test e, Weldon Spring, Mo., Fernald and Portsmouth, Ohio, and Pa-cah, Ky., reported a total of 3,309,000 cubic feet of radioactive waste ried during fiscal year 1961. The Oak Ridge and Idaho burial sites, ich were designated as interim locations for use by licensees in dis-sing of suitably packaged low-level solid radioactive wastes, re-rted a total of 74,400 cubic feet of such wastes buried for licensees der this Interim Burial Program and 20,600 cubic feet of waste ried for other Government agencies. The remainder of the 3,309,000 bic feet was generated by Commission and contractor activities and nsisted of wastes ranging from low to high radioactivity which are ried, or stored, at the Commission-owned facility.

If, and when, the growth of the atomic energy industry shows a quirement for new low-level waste burial sites, the Commission ex-cts that State governments may wish to establish and control sites the benefit and convenience of their citizens. Currently, the State

of New York is proposing to establish a burial ground for low-level radioactive waste at its Western New York Nuclear Service Center in Cattaraugus County.

New Production Reactor

As of November 30, design of the New Production Reactor (NPR) at Hanford was estimated to be 91 percent complete, and construction was 37 percent complete.

During the late summer of 1961 a comprehensive review of the NPR construction progress and estimated cost was undertaken. As a result, it was found necessary to revise the scheduled construction completion from October 1962 to March 1963 and to increase the cost estimate from \$145 million to \$165 million, both of these figures excluding \$7.2 million for NPR supporting facilities.

During the year, the development program in support of the NPR project progressed quite satisfactorily. The fuel element development program and construction at Hanford of the necessary production facilities for the coextrusion and fuel element finishing operations proceeded to the point of initiation of fuel element production operations.

The NPR is a convertible reactor; that is, its design includes features which will permit the addition of electric power generating facilities. If such facilities are installed, the reactor could be operated for the dual purpose of plutonium production and electric power generation or could be operated solely for the production of power. In its past session, Congress did not authorize the installation of the power generating facilities.

In September, Washington State officials announced that in the absence of federal plans for construction of NPR generating facilities the State would consider sponsoring the project, since this could be done under existing legal authority. Subsequently, the State withdrew from active participation when the Washington Public Power Supply System (WPPSS) expressed interest in building the power plant. Negotiations are currently underway between the WPPSS, the Commission, and the Bonneville Power Administration to determine if suitable arrangements can be worked out. WPPSS' plans call for financing by the sale of revenue bonds.

Gas Centrifuge Studies

The Commission in 1960 increased the United States effort on the development program of the gas centrifuge process [9] for separating

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[9] See pp. 102–104, 123, 500–504, Annual Report to Congress (January–December 1960).

isotopes. It is expected that the total effort will be at a level of approximately $2 to $3 million per year. The current development work includes studies in three major areas including: (1) basic research at the University of Virginia, Charlottesville, Va.; (2) centrifuge experiments by the Union Carbide Nuclear Co. at Oak Ridge, Tenn.: and (3) development of advanced gas centrifuge units by the Garrett Corp., Air Research Manufacturing Division, at Los Angeles, Calif. In addition, a special theoretical group was formed to study the gas centrifuge. The work of all contractors involved in the program is administered by the Oak Ridge Operations Office.

As noted in last year's report, the Commission's review of the gas centrifuge process indicated further development work would be necessary before the centrifuges, which up to now have been operated only as single laboratory units, could be used in a production plant. Some of the areas in which problems must be solved before a satisfactory process is possible with the current centrifuges include: insuring the reliability of the present experimental machines for continuous long-term service; development of a model satisfactory for mass production; development of a method for introduction and removal of gas when the machines are operated in a group; and a determination of the auxiliary processes, services, and instrumentation necessary for plant operations.

During April 1961, the Commission amended its regulations to extend its access permit program to classified areas of the gas centrifuge field. By late 1961, one permit had been issued—to Dow Chemical Co.

United States-United Kingdom Information Exchange

United Kingdom representatives of the Commission and the U.K. held a series of meetings during 1961 on production program subjects of mutual interest. The principal items of discussion were feed materials, chemical processing, gas centrifuge, plutonium finishing, and production reactor operating philosophy. All discussions were unclassified with the exception of those pertaining to the gas centrifuge.

FISSION PRODUCT TRANSPORTATION

Parallel to the demonstration of improved processes for the recovery and purification of large quantities of radioisotopes at the Commission's Hanford, Wash., plant, two methods have been developed for transporting hundred-kilocurie quantities of semi-pure and pure fission products in a safe manner to Oak Ridge, Tenn., where they are further purified and formed into radioactive sources.

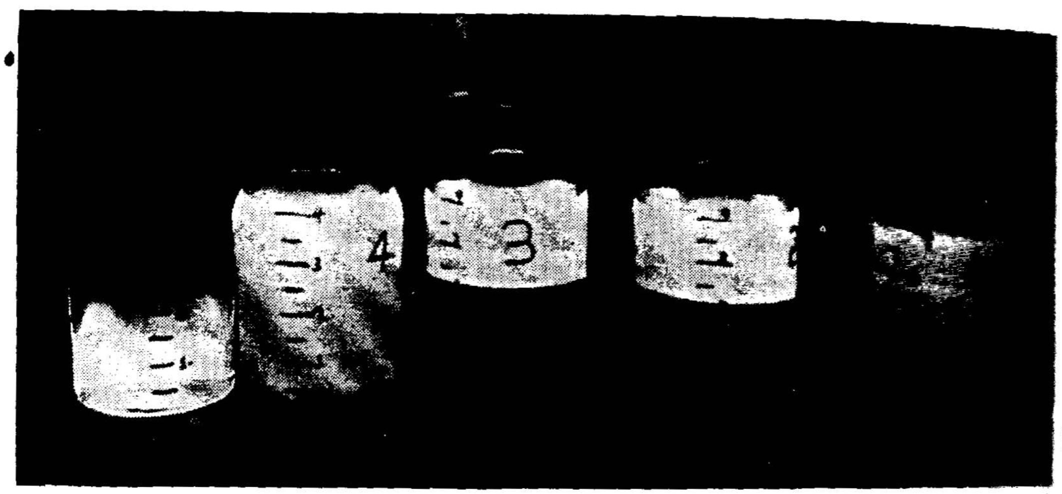
The first method involves fixation of the radioactive material on an inorganic ion exchange resin (Decalso) to permit a safe, semi-dry

shipment in a shielded cask. The second method is to accumulate a fission product precipitate, such as strontium carbonate or a sodium rare-earth double sulfate, on a woven stainless steel wire filter within a shielded cask, the cake then being shipped as a dry solid.

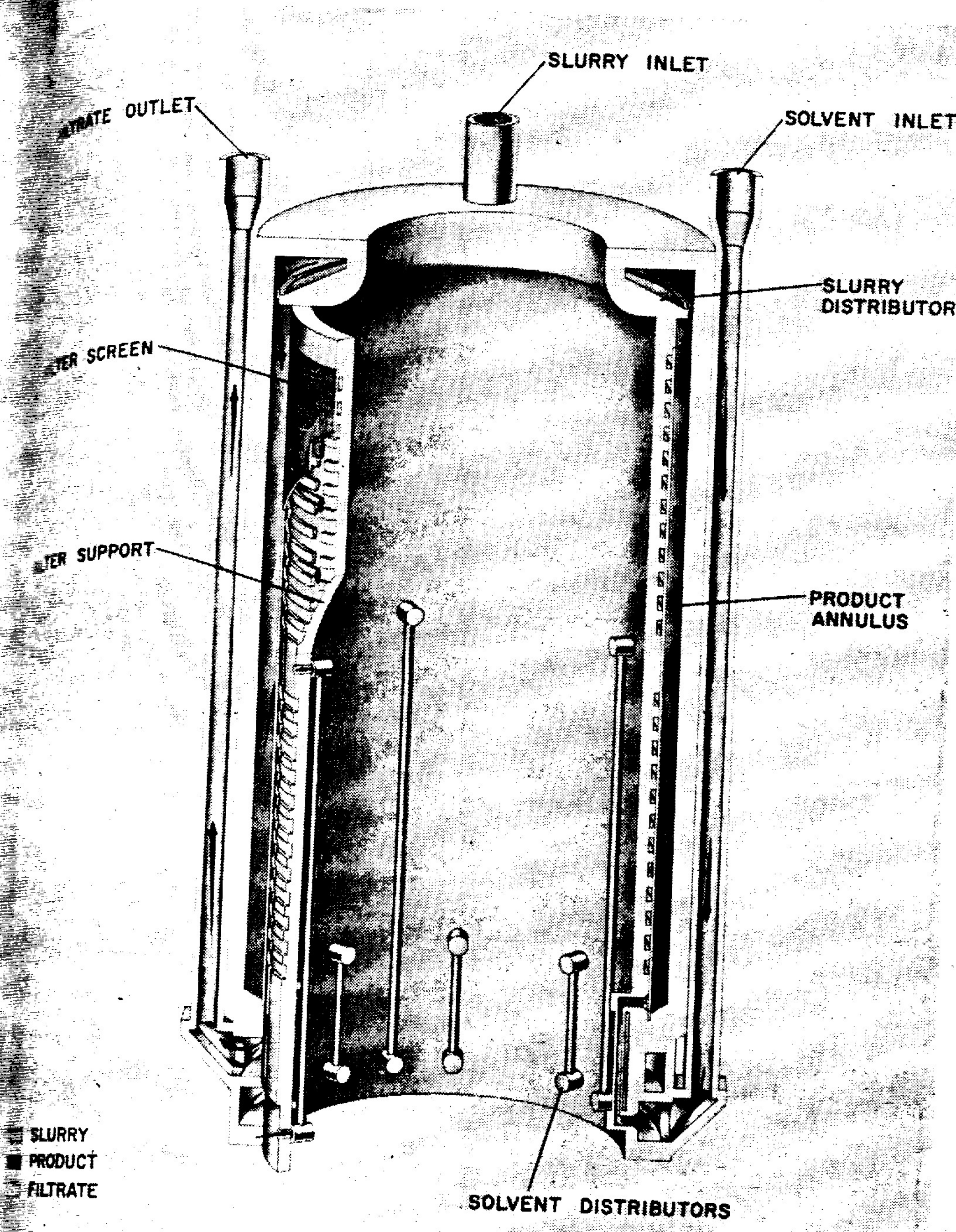
Fission product cesium is transported from Hanford to Oak Ridge in four shielded transfer casks, each of which can contain 30,000 curies of cesium 137 absorbed on 400 gallons of Decalso. Two of the cesium 137 casks are mounted on each of two specially modified gondola railroad cars which are reinforced with crash shields and roll-over supports to protect the casks. The strontium 90 is shipped in a shielded cask of high structural integrity which is within a buffer shield. The buffer shield provides protection against impact and penetration and is attached to a standard railroad flatcar or depressed center flatcar.

More than 250 kilocuries of cesium 137 and 180 kilocuries of strontium 90 have been safely transported from Washington to Tennessee by these methods. Similiar techniques and methods can be used in the future to safely transport large quantities of semi-pure or purified fission products to private processors elsewhere who are engaged in the manufacture of products containing radioactive materials.

The following five pages show the main components of the transportation system developed by General Electric Co., the Commission's contractor-operator of the Hanford plant.



Strontium Glow. Some four gallons of highly radioactive liquid strontium 90 glows in the darkness of a heavily shielded radiochemical cell at the Commission's Hanford, Wash., plant. Photographed through four feet of leaded glass shielding, the liquid was part of the first multi-kilocurie shipment of strontium 90 made from Hanford to Oak Ridge National Laboratory, Tenn., and represented the beginning of the first major program for recovery and utilization of byproducts from the Hanford plutonium production process. The strontium 90 is being recovered from the fission product waste stream. Its characteristic glow is a useful indication of its progress through the recovery process since all work on the highly radioactive element must be done remotely.



ter-Container. Diagram of the annular product container which accumulates fission products in a thin layer on a screen. The annular container reduces temperature drop through the powder and also provides additional surface heat transfer. The annular space is ⅝-inch thick; the inside diameter is inches; the overall height is 18 inches; and 150 cubic inches of material be contained. The fission products are collected on a woven stainless steel which is supported by lands formed by a series of horizontal and vertical oves. The horizontal grooves increase the open area behind the filter screen the vertical grooves provide a path for the filtrate to flow out of the filter.

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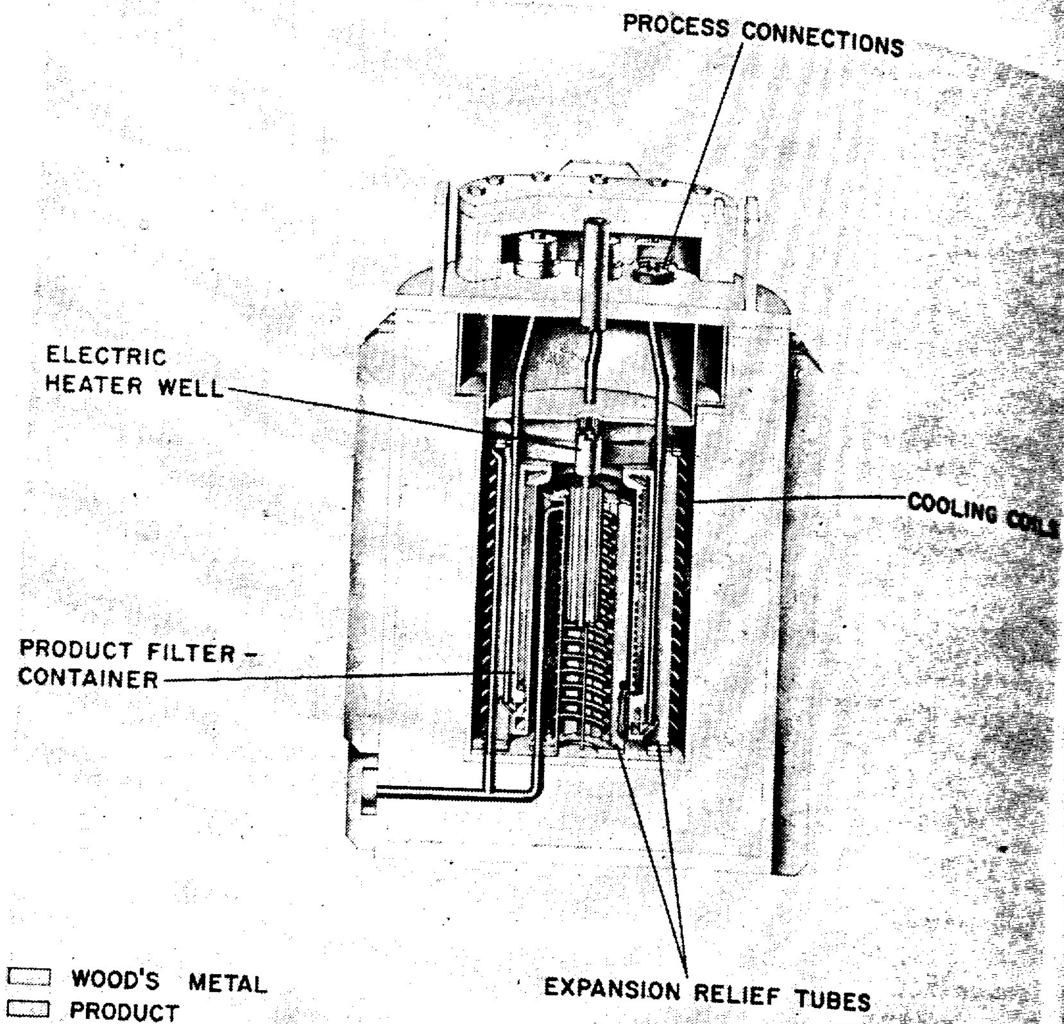

Shipping Cask. Diagram of the assembled shipping cask with the fission product container and the cask cover in place. The cask cover helps support the product container and includes the process connections for loading and unloading the product container. The cask is an externally finned, lead-shielded, cylinder with the lead shielding confined by a 1-inch thick steel outer shell and a ½-inch thick steel inner shell. The assembled cask is about 3½ feet in diameter, about 4½ feet high, and weighs 18,000 pounds.

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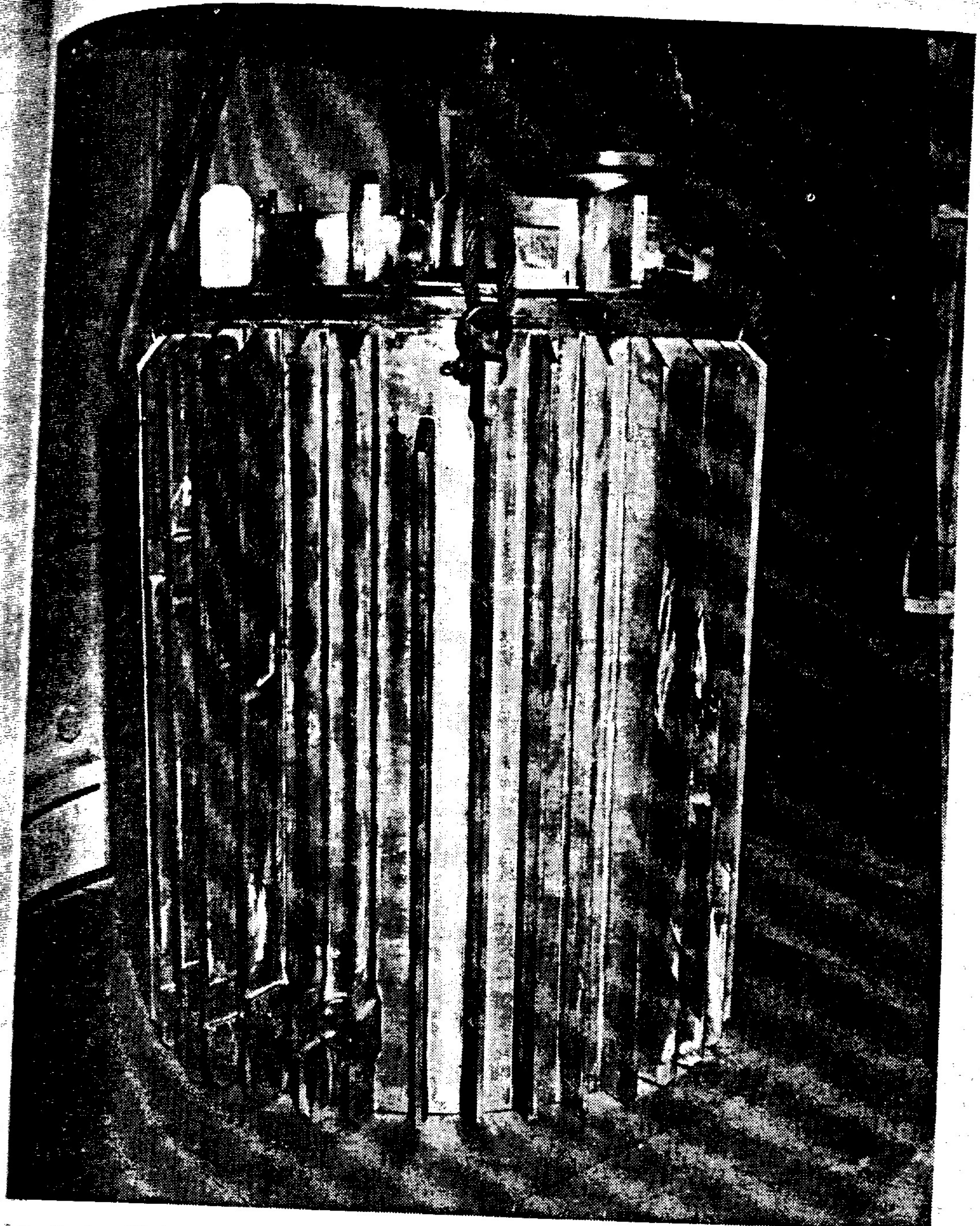
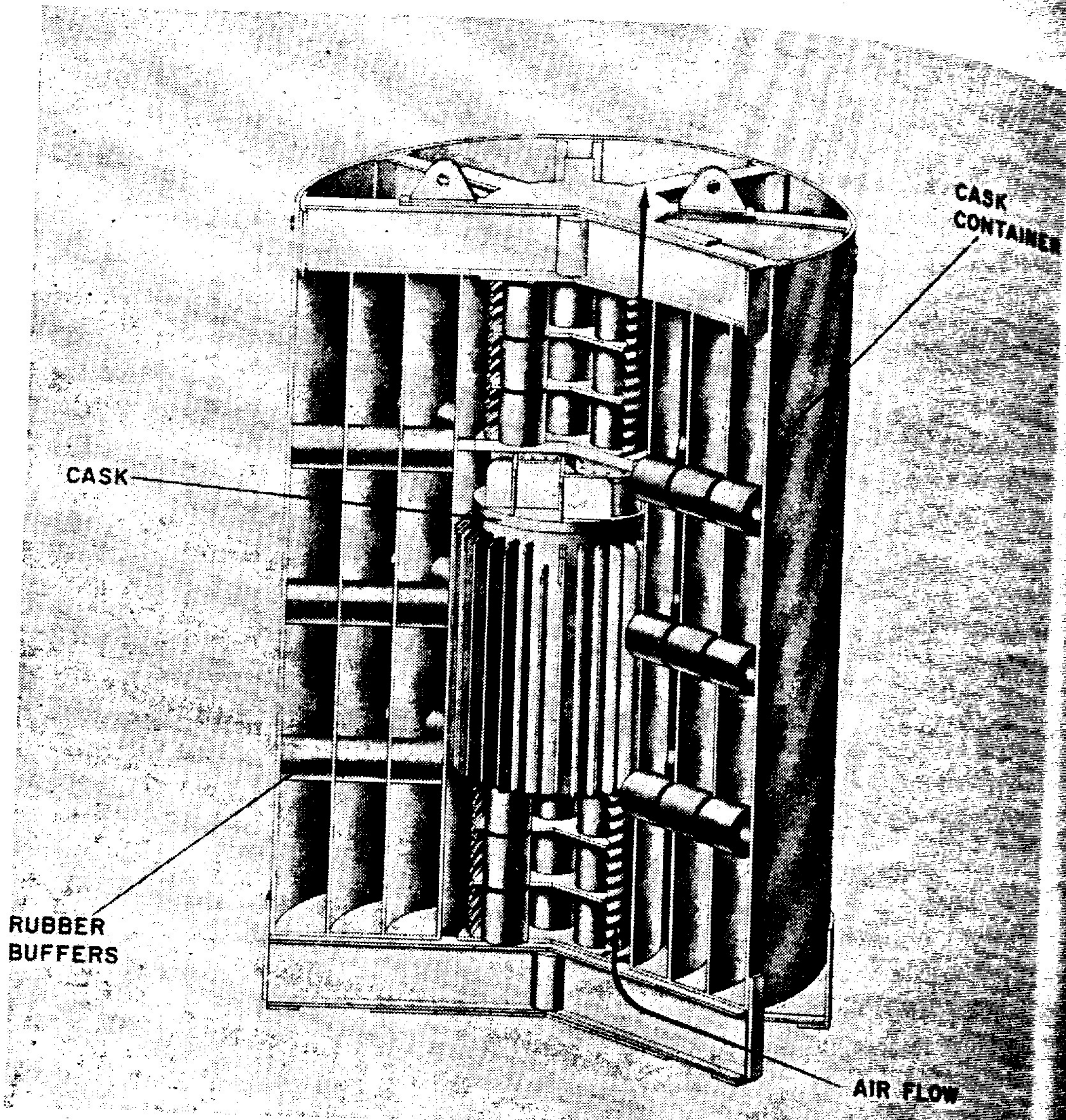
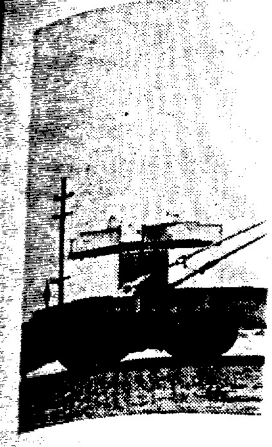


ary Cask. Weighing nine tons, the strontium 90 shipping cask can withstand a force normal to the surface in excess of 50 times the force of gravity (50 G). The external fins serve a threefold purpose: (*1*) they assist heat dissipa-tion by spacing the cask within the cask container and by providing additional -ding surface area; (*2*) they stiffen the outer steel shell; and (*3*) they assure -ad distribution from the container to the cask in the event of impact.



Complete Unit. This diagram shows the cask container with the cask in place. The container was designed to reduce the decelerating forces imposed on the cask, to distribute these forces over the cask surface, and to permit the air flow required for the dissipation of the heat generated by the decaying radioisotopes. The cask container consists of four concentric, steel shells which extend above the cask and below the bottom of the cask and separated by short, rubber columns. At the top and bottom of the container, heavy steel spiders are solidly attached to the outer container shell thereby making it strong against end, side, or edge impacts. The cask container is about 8 feet in diameter, 12 feet high, and weighs about 23,000 pounds without the cask in place.



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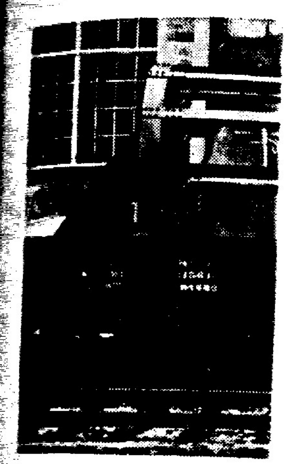

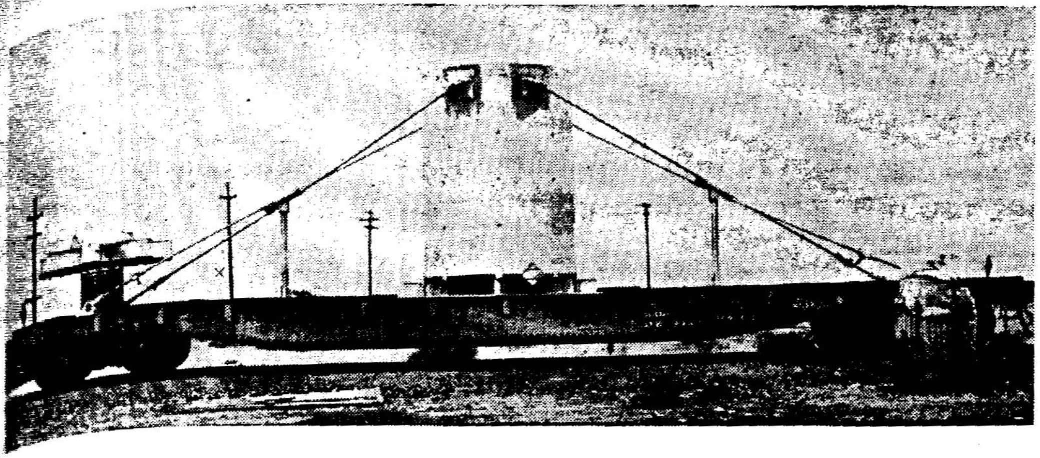

Shipping Systems. Upper photo shows one of the flatcars and components used for transporting strontium 90 from Hanford, Wash., to Oak Ridge, Tenn. At the right of the car is the cask itself covered with plastic to keep dust from lodging on the outer surface; in the center of the car is the outer container, rigidly attached to the car by tie rods which are safe for forces considerably greater than those encountered in normal railroad shipping; and on the left is the cover for the container. *Photo below* is one of the railroad gondola cars modified to protect the two casks of cesium 137 it carries. These casks are larger than the strontium 90 casks, having a capacity of 550 gallons. They are lined with 3½ inches of lead shielding and weigh 15 tons when empty.

RADIOISOTOPE DEVELOPMENT

Highlights of the Commission's program to expand and accelerate the growing beneficial applications of radioisotopes during 1961 included:

- Byproduct material licenses at November 30, 1961 surpassed the 9,000 mark, showing an eight percent increase over the 1960 figure and marked by an eight percent increase in industrial licenses.
- Production and sales of radiosotopes reached new levels as 438,2[illegible] curies of radioisotopes were distributed, and $2.7 million worth of sales were recorded.
- The largest single shipment to a licensee in Commission history of a radioisotope source—50,000 curies of cobalt 60—was made.
- Improved processes for separation of radioisotopes from fission products made the large quantities of high-activity wastes produced at the Commission's Hanford, Wash., plant a prime source of specific radionuclides for Oak Ridge National Laboratory's source fabrication work.
- The largest number of multi-kilocurie sources of radioisotopes in the Commission's history were fabricated for use in gathering scientific data, providing navigational aids, and research on pasteurization of foods.
- More new types of radioisotopes were made available in sufficient quantities for practical use in the medical and industrial fields.
- Construction was virtually completed on the High Intensity Radiation Development Laboratory at Brookhaven National Laboratory.
- The Fission Product Development Laboratory (formerly called Fission Product Pilot Plant) resumed operations; construction of the Radioisotope Process Development Laboratory is on schedule and should be completed by mid-1962.
- Radioisotopes were being used to power transmitting equipment in orbiting TRANSIT satellites and an unmanned weather station in the Arctic; fabrication was underway on a radioisotope power source for an ocean-bottom, automatic seismograph station that will be emplaced during early 1962.
- New uses continued to be developed for beneficial utilization of radioisotopes, ranging from hydroelectric turbine calibration, to oil recovery, to detection of hidden defects in growing trees.
- Studies on radiation pasteurization of foodstuffs were enhanced by the fabrication and erection of three 25,000–35,000-curie cobalt 60 research irradiators.

PRODUCTION AND SALES

Resumption of operations in the Fission Product Development Laboratory (formerly designated as the Fission Product Pilot Plant) at Oak Ridge National Laboratory (ORNL) during August of the past year resulted in an increase in production and sales of radioisotopes. As of November 30, a total of 438,205 curies had been shipped during 1961, as compared with the 191,122 curies shipped for the same period of 1960, and the 222,703 curies shipped during the first 11 months of 1959. A parallel rise in gross income from radioisotope sales was also recorded—$2.7 million as of November 30, as compared with the $1.9 million in 1960, and the $2.0 million in 1959.

Radioisotope Distribution

As of November 30, 1961, the total amount of radioactive material distributed in 156,236 shipments from ORNL—the Commission's principal shipping point for radioisotopes—during the 15-year-old radioisotopes distribution program was 1,557,784 curies.

During the past year, there have been some unusually large increases in the amounts of certain radioisotopes shipped. For example, cobalt 60 shipments rose from 133,000 curies in 1960, to 235,298 curies during the first 11 months of 1961; and strontium 90 increased from 338 curies in 1960 to about 98,000 curies in the past year. The dramatic increase in strontium 90 is due to demand for the radioisotope as heat-electrical power sources to be used in remote weather stations. The heavy demand for cobalt 60 is attributed to the need of secondary distributors to build up inventories to meet increased demands for teletherapy and radiographic sources. An unusually large amount of carbon 14 was sold during 1961—40 curies, as compared to the average of 7 curies per year recorded previously.

As of June 1, 1961, firm orders were on hand at ORNL for 330,000 curies of cesium 137. It is estimated that 50,000 curies of this backlog had been filled by year's end, leaving a backlog of about 290,000 curies for 1962. Interestingly enough, two orders from secondary processors for over 100,000 curies each account for most of this backlog. A large share of ORNL's business includes supplying bulk quantities of radioisotopes to commercial processors who "package" radioisotopes for re-sale.

Record Shipment. Photo shows Oak Ridge National Laboratory employees working behind four feet of lead glass shielding and using master-slave manipulators, loading a 50,000-curie cobalt 60 source. The source, largest in the laboratory's history to be shipped to an individual licensee, is being used by the National Bureau of Standards. Photo shows one of the 12 capsules of cobalt 60 being inserted (left arm of manipulator) into the container while the other arm holds a mirror showing the inside of the container.

Record Shipment

The largest single radioisotope shipment to a licensee in the history of Oak Ridge National Laboratory was made on March 29. A shipment to the National Bureau of Standards, Washington, D.C., totaled approximately 50,000 curies of cobalt 60 and was roughly double the largest single shipment previously made from the laboratory. The previous record shipment was 22,900 curies of cobalt 60 to the Budd Co., Philadelphia, Pa., on October 4, 1960.

The National Bureau of Standards plans to use the cobalt 60 for studying effects of radiation on various materials and for fundamental research on dosimetry. The shipment, made up of 12 capsules each containing several small wafers of cobalt 60, was made in a specially-designed five-ton lead container provided by the Bureau. The container was designed with provisions for cooling water to dissipate the heat generated by the radiation sources. The Bureau transported the shipment by truck.

Cobalt 60, one of the more widely used radioisotopes in the indus-al and medical fields, is produced by subjecting non-radioactive balt to bombardment by neutrons within a nuclear reactor. After period of several months in the reactor, the highly radioactive cobalt ready for packaging into radiation sources of various sizes.

Oak Ridge National Laboratory is the principal supplier of radio-topes in the United States.

Isotopes Development Program

Under the isotopes development program, emphasis is being given developing large-scale economic uses of fission product wastes ated by nuclear reactor operation. Such utilization of these fission oducts is important to the total nuclear energy development pro-am in the United States because this represents the largest, and tentially the most economical, source of radioactive energy to isfy future demands for radiation sources and heat-power sources. ilization of the waste may become important in waste disposal ntually and will, in any case, provide some income to offset the ra costs of ultimate waste disposal. The principal effort in re-arch and development is also directed toward developing means ereby radioisotopes, and especially the radiation emanating from lti-kilocurie radioisotope sources, can help solve long standing na-nal problems in food distribution, control of environmental pollu-n, and water resources development and furnish information eded by meteorologists and seismologists. Major subdivisions of s program include radiation pasteurization of foods, radiation ocessing development, radioisotope technology development, radio-tope process control and production development, and radioisotope ining and education.

Radioisotope Production Development

proved Production

Continuing progress was made during the reporting period in re-arch and development on new isotopes to meet the changing needs science and technology for a wide variety of radiomaterials. ndard radioisotope preparations were improved in quality and de more readily available, and prices were reduced.

During 1961 a successful demonstration was made by the Hanford oratory of a high-efficiency solvent extraction process for the re-ry and purification of strontium 90; a 5-watt and two strontium 90

power sources of about 10 watts were completed for the U.S. Weather Bureau, Coast Guard, and Navy; most of the work was finished on a 5-watt cesium 137 power source for Lamont Geological Observatory; and methods and equipment were developed and demonstrated for the safe transportation of 100,000-curie bulk quantities of cesium 137, strontium 90, and cerium 144. In addition to these major items, fission product isolation processes were improved; large scale reactor production of iodine 125 was initiated; the previously mentioned 50,000-curie cobalt 60 source for the Bureau of Standards and three 30,000-curie cobalt 60 sources for food research irradiators were fabricated; and production techniques for cadmium 109, calcium 47, copper 67, europium 155, iodine 129, iodine 130, technetium 99, and xenon 133 were improved.

Fission Product Heat-Electrical Power Sources

Fission product sources totaling more than 750,000 curies of strontium 90, 330,000 curies of cesium 137, and 1,000,000 curies of cerium 144 were fabricated during 1961, or were in production, to meet needs for radioisotope electrical power units, heat sources, and radiation sources for a variety of applications. The first large fission product power source (strontium 90) produced in 1961 is now supplying power for an unmanned weather station transmitting meteorological data from Canada's remote Axel Heiberg Island. The source was fabricated at Oak Ridge National Laboratory, using radioisotopes that had been recovered at Hanford from fission product wastes. The strontium 90 is a byproduct of the chemical processing of used reactor fuel elements. The solution was reduced to strontium titanate and then pressed into eleven pellets of about 1,600 curies each. After sintering, the pellets were placed in a capsule, welded, and checked for leak tightness. The entire operation was performed at ORNL's Fission Product Development Laboratory behind heavily shielded cells because of the high levels of radioactivity. The 17,500-curie source is 1,500 times larger than any strontium 90 source previously prepared at ORNL.

Two additional, and still larger, sources were prepared and shipped from the Oak Ridge National Laboratory to The Martin Co. in Baltimore for insertion in thermoelectric generators. These sources contained 40,000 curies. The first will produce 250 thermal watts of heat and 12 watts of electricity for use in powering a weather data telemetry unit. In this case, strontium carbonate was converted to 1,280 grams of strontium titanate in the Oak Ridge National Laboratory's Fission Product Development Laboratory. The titanate was then con-

rted into 28 ceramic pellets, each having about 1,400 curies of activity uivalent to about 9 thermal watts. Seven pellets were placed in ch of the four Hastelloy C capsules which were then welded reotely. Krypton 85 was utilized in checking the welded capsules for k tightness. The 17,500 curie strontium 90 titanate source for the att weather station unit and two similar 40,000-curie sources for e Navy (SNAP 7C) and Coast Guard (SNAP 7A) were fabricated ORNL. The fabrication procedure for these strontium 90 titanate urces was developed cooperatively by ORNL and The Martin Co. he power units for the sources and the source capsules were conructed by The Martin Co. under Commission contract.

Delivery of 100-kilocurie quantities of pure strontium 90 carbonate The Martin Co. facility at Quehanna, Pa., will begin by early 1962. artin will fabricate and assemble two 60-watt strontium 90 titanate wer generators (SNAP 7B and SNAP 7D) for the U.S. Navy and U.S. Coast Guard utilizing a total of approximately 600 kilograms.

Fabrication of a 28,000-curie cesium 137 polyglass source for an ean floor seismograph power unit to be tested by Lamont Geological bservatory was scheduled for completion by Oak Ridge National aboratory in December 1961. The cesium 137 power units were deloped by the Royal Research Corp. under Commission contract.

Processes for isolation of large quantities of specific fission products om reactor fuel reprocessing effluents were demonstrated at Hanrd. A one-megacurie quantity of strontium 90 was isolated from the urex chemical reprocessing waste stream and an ion-exchange ocess for purification of strontium 90 and promethium 147 was monstrated. At ORNL, improved cerium 144 and technetium 99 rification processes were developed. ORNL is now purifying chnetium 99, an element which does not exist in nature, in kilogram antities as the pure metal or ammonium pertechnetate. This rare ement has excited interest because of its potential as a super-conctor and corrosion inhibitor. Recovery of cesium 137 from aged stes at Hanford has assured, for ORNL fabrication work, large antities of a pure product, that has a low content of cesium 134 ich is a more penetrating gamma emitter than cesium 137 and erefore introduces shielding problems.

An outstanding accomplishment has been the successful demonstran of a new solvent extraction process, developed at ORNL, for isolation and purification of strontium 90, cerium 144, and the er rare earths. The first test run at Hanford of the process for al purification of strontium 90 resulted in production of 200,000 ries of pure strontium 90. The product was isolated by a precipitaprocess in the Hanford Purex plant from fission product wastes at had been aged about one year to permit the decay of strontium 89.

Neutron-Capture Radioisotopes

Continued improvements in processing procedures, better production methods, and use of enriched stable isotopes as targets have resulted in greater variety and lower cost of radioisotopes produced by neutron irradiation of target materials in reactors. New isotopes of particular interest, which were made generally available during 1961, include calcium 47 and iodine 125.

Calcium 47 is a radioisotope that is of importance in medical diagnosis, particularly for diagnostic and research work related to metastatic bone cancer.[10] Its use as a tracer has made possible the location of metastatic cancer of the bone several months before it could be recognized by conventional methods such as X-ray photography. Calcium 47 is produced by neutron bombardment of enriched calcium 46 which has been separated electromagnetically from other calcium isotopes at ORNL. During the past year, the gain in quality by reducing the amount of undesired Ca^{45} from a ratio of Ca^{47}/Ca^{45} :: 10/1 to 25/1 is most significant.

Iodine 125 [11] has a relatively long life of 60 days and a low integral dose when deposited in body tissues because of the absence of beta radiation. In medical diagnosis it shows great promise for thyroid gland studies, blood plasma volume determination, and brain tumor localization. Iodine 125 is produced by reactor irradiation of xenon of natural isotopic composition at ORNL. Studies are in progress on the use of enriched xenon target material and continuous production processes to make this valuable radioisotope even more readily available.

Safety Criteria for Sealed Sources

The predominant industrial use of radioisotopes in this country is as sealed sources. Since the number and diversity of uses of sealed radioisotope sources, in new and varied designs, are expected to expand continually, the Commission has undertaken a research and development program to develop standard safety criteria for a wide range of sealed sources.

Source performance is being evaluated by Battelle Memorial Institute under a variety of conditions—thermal, mechanical, chemical, radiation and pneumatic—which might be encountered under both normal and abnormal conditions of use. The information generated by this program will help to accelerate the peaceful uses of radioiso-

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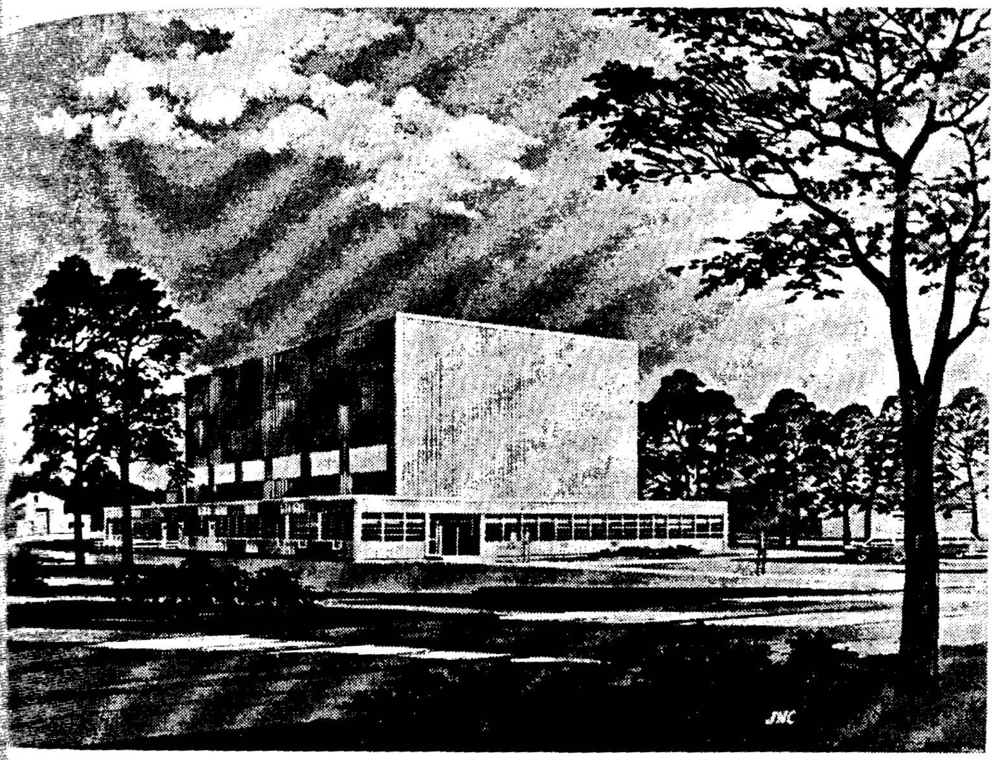
[10] See p. 16, "Atomic Energy Research in the Life and Physical Sciences—1960".
[11] "Atomic Energy Research—Life and Physical Sciences, Reactor Development, Waste Management—1961".

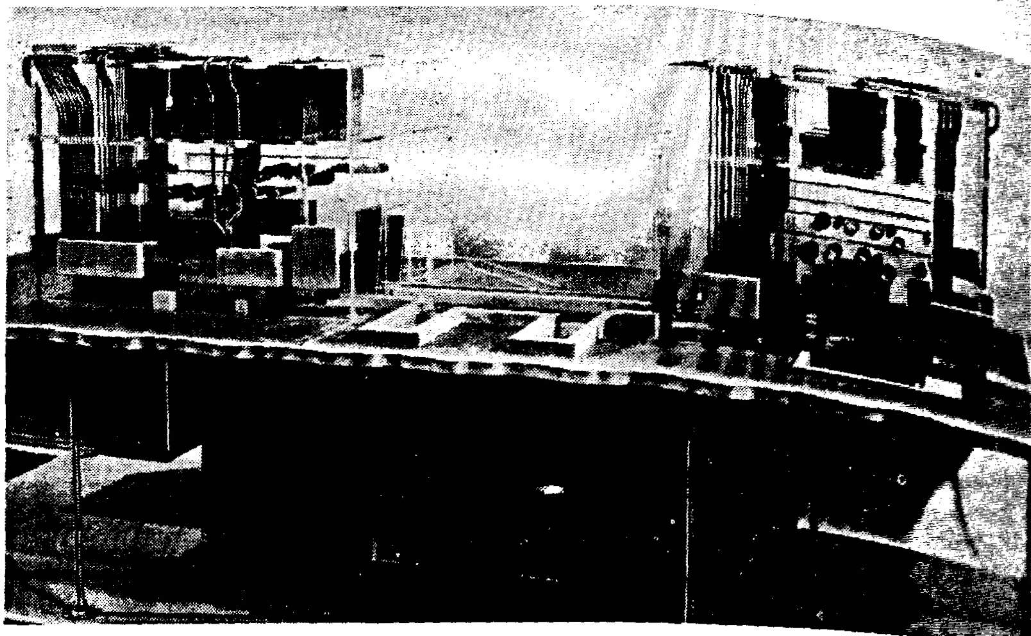
...s by (a) providing regulatory groups with technical guidance ...stablishing safe and practical regulatory practices and (b) giving ...ufacturers definite test goals to meet.

Industrial Process Radiation Development

The use of high-intensity ionizing radiation as a processing agent ...resents an important potential for the production of new and ...que materials as well as the improvement of existing products. The Commission's program in this area is directed toward improv... existing radiation technology. During 1961 appreciable progress ...s been made in the following areas: basic studies of pertinent reac... mechanisms and means of their control; design of high-intensity ...iation sources of various types to support research on radiation ...ocessing with emphasis on efficiency and safety; and studies of ...iation process feasibility.



...Laboratory. Artist's sketch of the High Intensity Radiation Development ...ratory now under construction at the Commission's Brookhaven National ...ratory. The laboratory is expected to be completed during the early part ... The laboratory will be used to obtain engineering data on a variety of ...tion sources in the million-curie range; in the development of more effi... techniques for handling large-scale radiation sources; and in training ...ists and engineers in the uses of such radiation sources for research pur... and industrial applications.



Unique Cells. The High Intensity Radiation Development Laboratory will utilize two unique cells. The model shows the Preparation Cell (on *right*) where various types of sources will be prepared for experimental use. The cell can also be used for irradiation experiments or any other types of experiments requiring remote handling. On the *left*, is the Irradiation Cell which includes lead-glass shielding windows, remote control manipulators, and periscopes. Here, materials will be exposed to the radiation sources for high-level irradiation studies and evaluation of various geometric arrangements of sources. Between the two cells is a 45-foot long canal, 16 feet deep, and with a 20-foot deep storage pit in the center. The canal will serve for transportation of high intensity sources between the two cells, the water serving as a shield during the transfer process. Wood blocks on the model indicate control panels.

Radiation Engineering

In order to generate the engineering design and operational knowledge essential to expansion of the potentials of process radiation, the Commission is constructing a High Intensity Radiation Development Laboratory (HIRDL) at Brookhaven National Laboratory. Construction began November 28, 1960, with completion scheduled for the early part of 1962. This facility will provide a unique concentration of personnel and equipment for the advancement of technology in the design and standardization of high-intensity radiation sources; in the dosimetry and radiation safety of large-scale irradiators; and in the design of irradiation facilities.

Much Commission-sponsored research on radiation process technology is adaptable to both radioisotope and electron-beam processing. For example, during the past year, radiation graft polymerization to form unique plastic materials—a process developed previously in Commission laboratories using radioisotopes—has become an important

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ustrial technique utilizing machine radiation. These products ve been very useful in the space program since they are able to withnd extremes of temperature.

In addition to Commission activities, commercially sponsored aped radiation research has continued with the development of new terials with unique properties. These include: improved wire inlation, new plastic food wrapping material, battery separator memanes, sterilized medical supplies, water desalination membranes, and lymer film with improved dye characteristics.

ocess Research

A variety of Commission-sponsored investigations are contributing process radiation technology. In all, the Commission had 14 conts in effect during 1961 in this area.

Continued research at Radiation Applications, Inc., on methods of ering the radiation level required to vulcanize monomer-polymer tures may reduce the present production cost of such materials as radiation-polymerized polyethelene wire insulation now used in ded missiles.

Studies of the effects of additives also by Radiation Applications, increasing the yields of radiation graft polymerization reactions result in reduced production costs of new plastic films. These exhibit unique and valuable properties but are at present costly produce.

The effects of ionizing radiation on increasing the sedimentation e of sewage are being investigated by Universal Match Corp. Sucsful development of this technique could appreciably increase the acity of existing sewage plants, or reduce the size of proposed age treatment basins.

Continuing studies of the nature of the mechanisms of various radin-induced reactions related to radiation processes have been prong valuable technical data which contributes directly to better erstanding of key reaction mechanisms. This work is being done William H. Johnston Laboratories.

Research on the influence of molecular structure on graft copolyization reactions by Battelle Memorial Institute is providing wledge that will eventually allow chemists, using radiation, to ide "tailor made" unique plastic materials.

Creation of new and unique textile materials having a wide range aluable properties such as mildew resistance, water proofing, and h resistance is a promising use of radiation being investigated at h Carolina State College.

Continued research on the radiation synthesis of metals is establishing the technical feasibility of producing such valuable ultra pure metals as silicon for semiconductor use. This work is being done by Technical Research Group, Inc.

Continuing progress in source design criteria and handling techniques has been made with regard to large (thousands to millions of curies) cobalt 60 and cesium 137 sources. Effort has also been expended on safety aspects of the entire process radiation program.

New experimental ceramic beta sources utilizing strontium 90, promethium 147, and cerium 144 have been fabricated by Radiation Applications, Inc., and are undergoing tests at Long Island City, N.Y.

Isotopes Technology Development

A broad spectrum of radioisotope potentialties are being explored under the Commission's isotope technology development activities. Principal program areas include: isotopic power systems, safety testing of radioisotopic materials, activation analysis, low-level tracer process control, isotope measurement systems, radiometric analyses, radiation absorption analysis, radioisotope fluid dynamics techniques, ionization technology, and non-destructive testing. During the past year, emphasis has been placed on a search for new principles of radioisotope applications with broad scientific and engineering implications.[12] In all, some 70 research and development projects are advancing technology in these areas. The work is being done at research centers, universities, industrial organizations and other government agencies. In 1960, there were 64 such technical projects.

The most striking example of isotope technology development during 1961 was the successful demonstration of the feasibility of isotopic power as a reliable source of electric power to meet unique requirements for exploration of space. The use of isotopic power in the TRANSIT satellites is discussed under the SNAP program in the Military and Space Applications section of this report. Of equal importance is the use of radioisotopic devices for telemetering data from remote regions of the world and from the ocean floor.

Particular attention is also being paid to isotope technology having potential benefits in meteorological data collection, environmental pollution control, assurance of food and drug purity, crime detection and water resource development. In these public benefit phases of isotope development, some emphasis is given to engineering of isotopic devices and to production of test equipment for specific purposes. Commission research in these areas is of assistance to public, state and municipal organizations.

[12] See Appendix 4.

Advanced research has also included investigation of the possibili-ties for applications of neutrons in gaging and nondestructive testing by improvements in neutron production and image formation. Prompt radiation emitted in neutron capture processes presents gaging potentialities not realized by the usual radioisotope decay radiations.

ation Installation. The unmanned weather station was installed on bleak Axel Heiberg Island in the Canadian Northwest Territories during August 1961. Photo shows the strontium 90 source being lowered into its hole. In the back-ground (center) are the radio transmitters which will fit atop the power source. (The unit is similar to the one shown on page 68.) The station will automati-cally collect and transmit weather data at three-hour intervals. The entire unit is designed to operate maintenance-free for several years without refueling.

utomatic Weather Station

In August 1961, the world's first isotope-powered automatic weather station was placed in service by the U.S. Weather Bureau in coopera-tion with the Canadian Government. It is located on Axel Heiberg Island, a remote and uninhabited area in the Canadian Northwest Territories. The unattended station measures wind speed, wind di-rection, temperature, and barometric pressure and routinely transmits the collected data every three hours to manned weather stations lo-cated in Canada and the United States.

Power for the station is provided by a 5-watt strontium 90-fueled thermoelectric generator. The 112 thermal watts of heat from the radioactive decay of the strontium 90 is converted directly to elec-

tricity through thermocouples. Excess heat not converted to electricity keeps the station's electronic components warm, thus enhancing their operating reliability under the severe Arctic weather. The isotopic source is an insoluble and biologically inert chemical form of strontium 90, incorporated in a ceramic-type compound, strontium titanate.[13] This is securely sealed within a corrosion resistant capsule and a heavy lead shield to assure safety.

Particular attention was devoted in the design and fabrication of the automatic weather station to long-lived reliability commensurate with the isotopic power supply. The entire station has been designed to operate two years or more without maintenance, although the strontium 90 thermoelectric generator should provide usable power for up to ten years.

Underwater Seismograph Station

The need for more accurate information on earthquakes, leading to the possibility of predicting destructive shocks, is well recognized. Since recording of earth tremor frequency and distribution is presently limited by the fact that three-quarters of the world's surface is under water, a seismograph station that could be located anywhere on the ocean floor and automatically transmit its recorded data would add immeasurably to knowledge about earth movement.

In cooperation with Columbia University's Lamont Geological Observatory, the Commission has designed and started construction of such an isotope-powered seismograph station at Royal Research Corp. A thermoelectric generator which directly converts the heat produced by the radioactive decay of cesium 137 into five watts of electricity will be used to power an experimental station to be placed on the floor of the Atlantic Ocean early in 1962.

The cesium 137 thermoelectric generator will have a cylindrical shape, 30 inches high by 13 inches in diameter, and weighs slightly over 400 pounds. The cesium 137, which is contained in an insoluble and unreactive form called cesium polyglass (a calcium cesium aluminum borosilicate), is securely packaged in a corrosion-resistant capsule and shielded by depleted uranium. Even if the capsule were broken, the cesium polyglass would resist the corrosive action of sea water for many years. The entire generator is protected by a two-inch-thick aluminum alloy shell that will permit operation at ocean depths of 36,000 feet.

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[13] See pp. 188–190, Annual Report to the Congress (January–December 1960).

Water Resources

Radioisotope tracer techniques offer a unique means for obtaining better understanding of the underground flow of water and ground water reservoir recharge. Assurance of adequate water for growing public and industrial needs is of equal interest to technologically advanced nations as well as to arid regions of the world. The Commission is cooperating with the U.S. Geological Survey and other agencies in applying radioisotope capabilities to this broad area of potential benefit.

A survey has been completed on applications of tracer and radionuclear techniques to water resources problems. The survey has covered the use of radionuclear techniques in the chemical, physical and biological analysis of water, in the tracing of surface and subsurface water, in the treatment of domestic and industrial water supplies, tracing of wastes and sediments, and in movement of moisture in soil. Special attention has been given to the use of tritium, krypton 85 and ruthenium 106 for tracing water and to the use of neutron absorption and neutron activation of stable isotope tracers in water. This survey provides guidelines for future development.

In an experiment at Lake McMillan reservoir, N. Mex., 150 curies of tritiated water were thoroughly mixed in the shallow reservoir and allowed to seep into its underground storage system. By using the isotope dilution technique and sampling downstream, where lake water emerges from springs and flows back into the Pecos River, an accurate estimate can be made of the volume of water held in storage at any time.

Turbine Calibration

Radiotracers may be used to help conserve water through a recently developed method of calibrating the flow through turbines in hydroelectric power plants. This method uses only a few millicuries of gold and offers a practical, inexpensive approach to turbine calibration by applying the total count method for accurate flow rate determination. Standard methods such as the velocity-flow and salt-dilution techniques are both expensive and time-consuming. Only a cupful of solution containing radiogold tracer is required as contrasted with several carloads of salt needed for the salt dilution method. The precision is greater than one percent. Broader use of isotopic turbine testing will contribute to water conservation by increasing the efficiency of hydroelectric power production.

Deep-water Isotopic Current Analyzer

Accurate determinations of slow moving currents in bays and estuaries are particularly important to the control of water pollution and silt formation. A device incorporating a radioisotope technique which is capable of measuring extremely slow water movements has been developed and will be field-tested by the Chesapeake Bay Institute of Johns Hopkins University early next year. The instrument basically consists of a neutron source and a cannister of stable materials, surrounded by a 30-inch-diameter ring of radiation detectors. The neutrons, striking the stable materials, generate very short-lived radioisotopes which are then released into the water. The time it takes for the radioactivity to reach a particular radiation detector provides an accurate determination of the rate and direction of the water currents. Radioactive dysprosium 165, for example, has a half life of only 75 seconds, yet can measure the flow of currents ranging between 1 and 10 cm/sec.

Radiotracers in Secondary Recovery of Oil

Commission field and laboratory studies are continuing, in conjunction with the U.S. Bureau of Mines, to optimize radioisotope tracer techniques as aids in recovering billions of barrels of oil known to be left in old reservoirs. Simultaneous field tests are being carried out in the states of Oklahoma, West Virginia, and Pennsylvania to evaluate new tracer techniques in three major secondary recovery processes. In each case, selected radiotracers are being passed between injection and production wells to yield information on the underground fluid dynamics involved in the processes.

Neutron Activation Analysis

When bombarded with neutrons, most elements become radioactive and emit identifying radiations. An important research and development aim is to make neutron activation a more rapid, economical, and convenient analytical tool. To further this purpose, the coupling of scintillation spectrometer data to digital computers is being investigated. The system will make practicable the automatic analysis of large numbers of samples for such things as soil nutrient, water pollutant, drug purity, and geochemical investigations. An automated system for the activation, selection, and gamma ray spectrographic analysis of 100-sample lots has been built and is now undergoing tests at Texas A&M University. If successful, this will represent a major step forward in broadening neutron activation technology.

technical feasibility of an activation principle in detecting explosives, as in airplane luggage, by neutron beam examination has been demonstrated by work done for the Commission at Catholic University, Washington, D.C. Practical application will depend on logistic and economic factors now being investigated. The investigation is being carried out in cooperation with the Federal Aviation Agency.

Scintillating Ion Exchange Resins

Inexpensive and sensitive instruments that can detect and measure very small concentrations of radioisotopes in water supplies, and in effluents from industrial processes and waste disposal plants, are needed in order to apply tracer methods in water conservation and pollution control. Efforts are proceeding at Tracerlab, Inc., on the development of scintillating ion exchange resins for this purpose. Ion exchange resins can remove tracer quantities of radioisotope-labeled substances from liquids, while scintillating materials can detect the radiation of minute amounts of radioisotopes, thus permitting sensitive qualitative and quantitative determinations necessary for research in these areas.

Radioisotope Mass Flow Meter

Devices currently used for metering the pipeline flow of foodstuffs being processed involve contact with the food. Thus, devices such as vane-type meters, require a sustained effort to maintain sanitation and wholesomeness of the product. A new nuclear radiation gauging technique having a unique capability for performing such flow measurements without moving parts touching the foodstuff has been developed by Armour Research Foundation and successfully demonstrated with milk as the measured medium. The U.S. Air Force has found that the system also has promise for metering cryogenic rocket fuels.

Detection of Defects in Logs and Trees

The lumbering industry would be benefited by improved techniques for easy and accurate detection of defects in living trees, construction timbers, and related wood products. A device incorporating a radioisotope source which measures the density of wood would be valuable in the grading of logs for various uses and revealing defects due to embedded metallic objects, rotten projecting limb stubs, included bark, and localized decay. A technique based on the backscatter effect of

radioisotopic gamma rays, as from cesium 137, now under development by the Research Triangle Institute in North Carolina appears promising for this purpose.

Radiation Pasteurization of Food

The Commission's program on radiation pasteurization of food is aimed at developing the technology necessary to demonstrate whether it is technically feasible and practical to use relatively low doses of radiation to extend the refrigerated shelf life of perishable foods. Any commercial application of low-dose radiation pasteurization of food, after the demonstration of technical feasibility, would be the responsibility of private industry.

The low-dose radiation pasteurization method involves irradiation with less than one million rad as contrasted with the three to five million rad high-dose irradiation [14] necessary for long-term preservation without refrigeration. The low-dose method promises to be the most immediately useful civilian application of ionizing radiation for food processing purposes since it could aid in better food distribution by making foodstuffs available in as near fresh condition as possible and minimizing processing effects on quality. It could also have economic value by making possible the distribution of near-fresh perishable foods in distant markets.

Programmatic planning studies by Stanford Research Institute and the Massachusetts Institute of Technology have been completed. Specific products have been selected for development, and a coordinated research and development program has been outlined. Studies necessary to demonstrate wholesomeness and to meet Commission and Food and Drug Administration requirements for public health and safety of marketable items have been defined. Research irradiators have been completed, and conceptual design studies of other facilities required have been made at the Brookhaven National Laboratory (BNL).

Irradiators

Three research food irradiators have been constructed and installed at the University of California (Davis), University of Washington, and Massachusetts Institute of Technology (MIT) to support research at these sites. Employing 25,000 to 35,000 curies of cobalt 60,

[14] Research on high-dose radiation sterilization of foods for non-refrigerated preservation is being conducted by the U.S. Army's Quartermaster Corps. The Army and Commission's programs are complementary.

units were developed specifically to provide on-the-spot irradia- services to the research organizations. The first irradiator was by Brookhaven and installed at Cambridge, Mass., during 1961 use by both MIT and the U.S. Department of Interior Techno- al Laboratory at Gloucester, Mass. The two West Coast irradia- also installed this year, were built by Process Equipment Corp., BNL specifications.

Studies have been initiated to design transportable units which be utilized at the harvest site or packing house in the case of or close to existing processing plants in the case of fish. These with a semi-production capacity, would be capable of demon- ing the practical feasibility of radiation processing and at the time aid in the determination of the economics involved.

Large central irradiation facilities located in areas where large ities of specific types of foodstuffs are harvested regularly and to the foods would be transported, and specialized in-plant facili- both capable of commercial production, are currently in the con- al design stages.

imental Research

University of California at its Davis campus is conducting re- on selected fruit products, relating radiation to the various harvest techniques in terms of shelf life extension, as well as ing such areas as food chemistry, microbiology, and patho- gy.

ms and haddock are being investigated through coordinated ams at the Massachusetts Institute of Technology and the De- t of Interior's Technological Laboratory at Gloucester, Mass. milar coordinated research effort exists at the University of gton and U.S. Department of the Interior Technological Lab- y in Seattle, Wash. Dungeness crab and flounder are the spe- ing investigated.

ing Feasibility

market feasibility study conducted for the Commission by the Department of the Interior Bureau of Commercial Fisheries ed a strong willingness by the fish industry to utilize the radia- ocess. The study concluded that the process could revitalize ing industry by expanding the fresh fish market to inland resently inaccessible because of the short shelf life of the fresh h.

Packaging

A study is being conducted for the Commission by the Continental Can Co. to review data on packaging technology. The study will recommend the type of a research and development program necessary to meet the packaging requirements of the low dose pasteurization program.

Wholesomeness

The Commission, during 1960, initiated studies related to the determination of wholesomeness and safety of radiation processed foods. The studies will ascertain the nutritional and microbiological wholesomeness, and the health aspects of perishable foods which have been irradiated by gamma radiation sufficiently to preserve them or to extend their life in storage. Results of this program are not yet far enough along for evaluation.

Radioisotopes Training and Education

The Commission's radioisotope technology training activities are intended to help incorporate appropriate background into the education of scientists, engineers, skilled workers, and technicians, and to inform the public concerning the benefits and safety of radioisotope applications. Approaches include assistance to colleges and universities in obtaining equipment to incorporate radioisotope training in their physical sciences and engineering curricula, faculty training course and training aid development, and production of films.

(Activities carried on during 1961 in this area are described in the Education and Training Section, Part 3 of this report.)

PLOWSHARE PROGRAM

The Commission's Plowshare program is directed toward demonstrating that nuclear explosives can be used for a variety of peaceful industrial, scientific, and civilian uses such as excavation projects, the tapping of water and mineral resources, and possible heat reservoirs. The program was given separate divisional status (Division of Peaceful Nuclear Explosives) within the Commission organization during 1961. Major activities during the year included:

• The first nuclear detonation experiment, Project Gnome, was successfully conducted in New Mexico on December 10.

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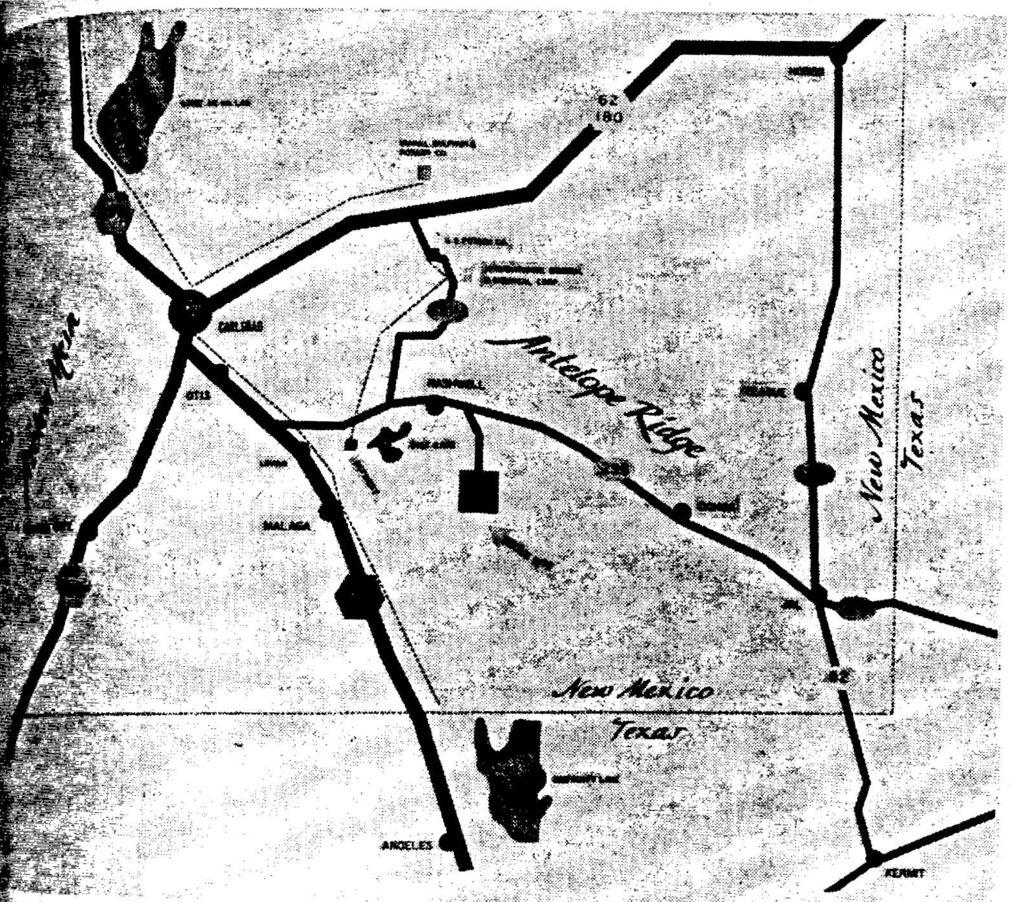
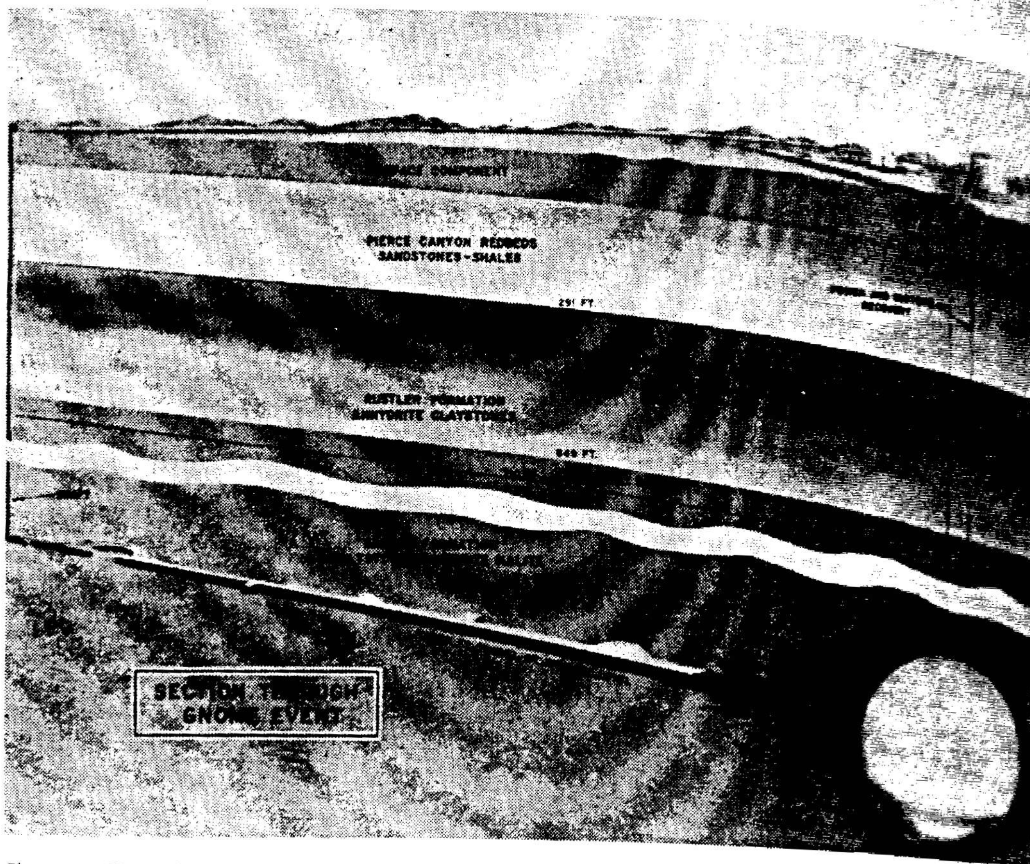
Planning and scientific environmental investigation for a proposed large-scale excavation (Project Chariot) in Alaska was continued.

Data obtained from chemical explosive (non-nuclear) field tests conducted by the Commission's Lawrence Radiation Laboratory (Livermore) provided a basis for relating theory to practice, information on the safety of explosives application, and information on the design and construction for tests of the applicability of nuclear explosives to peaceful uses.

Laboratory efforts were devoted to developing theories in two main areas of explosion effects: (1) excavations, i.e., application to construction of canals, harbors, water diversion projects, mining projects, and roads; and (2) contained-environment explosions, i.e., chemical reactions, oil recovery, mining projects, waste disposal, power production, and isotope production.



Gnome Location. Stylized map shows the location of Project Gnome, first nuclear detonation in the Commission's Plowshare program (dark square, center of map). The site is about 25 air-miles south of Carlsbad, N. Mex. Map also shows the location of the potash mines, north of the project site, which were evacuated as an added safety precaution before the detonation took place. The Plowshare program is being conducted to develop peaceful and practical uses for nuclear explosives in civil engineering, industrial projects, and scientific research.



Gnome Event. Artist's sketch shows how a 1,200-foot shaft was sunk into the thick sub-surface salt bed and then a 1,000-foot tunnel was dug laterally to an underground chamber where the Gnome nuclear device was detonated on December 10, 1961. Lines on right of photo show where holes were drilled into the area of the detonation to make studies of isotope and power recovery.

Field Experiments

All Plowshare field experiments are conducted by the Office of Field Operations (formerly Office of Test Operations) of the Commission's Albuquerque Operations Office; the planning and laboratory work associated with the field tests is done by, or in conjunction with, the Commission's Lawrence Radiation Laboratory (Livermore).

Project Gnome

First of the several peaceful experiment nuclear detonations planned under the Plowshare program, Project Gnome was successfully carried out near Carlsbad, N. Mex., on December 10, 1961. The approximately five kiloton nuclear device was detonated in an underground chamber approximately 1,200 feet below the earth's surface in the Salado Salt Basin, a thick subsurface salt bed about 25 miles southeast of Carlsbad.

carrying-out of Project Gnome was the culmination of field which had been underway since March 1960, and planning had been conducted since the formal inception of the Plow- Program in June 1957. President Kennedy announced his oval for conduct of Project Gnome on October 25, 1961, point- that the Project was "a further example of this country's to turn the power of the atom to man's welfare rather than truction."

project was conducted by the Commission's Office of Field ations and Lawrence Radiation Laboratory (Livermore), with ipation by Los Alamos Scientific Laboratory, Oak Ridge Na- Laboratory, Sandia Laboratory, Stanford Research Institute, Bureau of Mines, U.S. Geological Survey, U.S. Coast and Geo- Survey, and Department of Defense. The U.S. Public Health ice, U.S. Weather Bureau, Edgerton, Germeshausen and Grier, and Holmes and Narver, Inc., also participated in technical and safety programs.

Project was designed to provide scientific and technical in- ation for five major purposes: (1) the possibility of recovering al power from the heat generated by a nuclear explosion; (2) the ibility of recovering commercially or scientifically valuable iso- s produced by such explosions; (3) neutron physics and other tific theory; (4) effects of a nuclear explosion in salt; and (5) n principles useful in developing nuclear explosion devices ifically for peaceful purposes. In connection with each of these oses there were a number of experiments depending upon com- instrumentation, sophisticated scientific apparatus, above ground g systems, post-shot drilling, and physical observation and meas- ents. The experiment was one of the most heavily instrumented y nuclear detonation conducted by the United States.

December 10, 1961, the scheduled target date, the detonation took at 12 noon, Mountain Standard Time. Over five hundred offi- observers, including nineteen from foreign countries, viewed the ation from a point four and one-half miles from the surface the detonation chamber. The detonation had been delayed hours from the scheduled target time because of adverse surface conditions.

addition to being the first nuclear detonation in the Plowshare am and thus the world's first known nuclear explosion for peace- purposes, the detonation and its results, so far, mark a series of firsts. It was the first nuclear detonation conducted in the con- tal United States outside the Nevada Test Site since the Alamo- , N. Mex., detonation in 1945. The cavity created by the explo-

sion was the first known to have persisted for more than a brief period of time, confirming technical predictions and establishing the basic feasibility of a number of ideas which depend upon this effect.

At year's end, the tremendous job of analyzing and evaluating the data provided by the experiment had just begun. However, scientists working on the project believed that all experiments have yielded positive data. An extensive seismic research program was also conducted in connection with the detonation by technical personnel of the Department of Defense contractors in the Vela-Uniform program and by the U.S. Coast and Geodetic Survey. This program was considered highly successful. Seismic detection of the detonation has been reported from Japan and Sweden.

Immediately after the detonation, the ground surface above the explosion chamber heaved upward producing a permanent bulge found to be about two feet at its maximum point, and 2,400 pounds of high explosives located three-fourths of a mile from the surface zero point was detonated prematurely. The high explosives had been scheduled for detonation five minutes after the nuclear device to calibrate microbarograph recordings.

In connection with the explosion, which was contained underground and, as predicted, did not breach the surface of the earth, there was a release of radioactivity through the shaft, mostly in gaseous form. Very little radioactive particulate material was released to the atmosphere. The exact mechanism by which this escape of radioactivity occurred is not yet known. About five minutes following the detonation steam was observed issuing from the vertical shaft leading to the horizontal tunnel 1,200 feet underground. This flow continued for a few hours and then diminished, with a small flow visible through the next day. It appears likely that the steam released was created by the heating of the water naturally present in the salt around the detonation point. In order to insure public safety, precautions had been taken based on predictions of the extreme limits of credible events, singly or in combination.

The highest off-site recording of radiation at an inhabited place was one-twentieth of a roentgen per hour in transitory vapor that passed over a farm about ten miles northeast of Carlsbad. The highest of any field recordings occurred briefly on a highway 4.5 miles from the command post where readings showed 1.4 roentgens for a few minutes. The highway was blocked for more than two hours to avoid exposure to motorists. Seven vehicles, however, passed through the area prior to establishment of the road block, and later were washed to remove possible radioactive contamination.

On-site, a maximum reading of 10,000 roentgens per hour was recorded at the shaft head after the detonation. This decreased to

roentgens per hour within five or six hours and to one roentgen per hour by December 12. Within two days of the test, project employees were working in the vicinity of the shaft head without the need of protective clothing.

The safety program in other respects was also successful and no damage to the Carlsbad Caverns, off-site facilities, or mines was determined during post-shot inspection surveys. Miners returned to underground workings of nearby potash mines after completion of the inspections by late afternoon and evening of December 10.

Early qualitative and quantitative information indicated the following regarding the results of the experiment:

1. A cavity was formed and continues to persist. Re-entry into the shot region by drilling established this on December 22, when the drill bit entered a void at 1,089 feet. The devise was emplaced at 1,184 feet. There was no steam nor pressure in this cavity at that time. Later, on December 28, the second drill hole penetrated the cavity and established what appeared to be a floor at 1,188 feet. In the course of drilling through this floor on December 29, the drillers reported entering a "second void" at 1,235 feet. Penetrating twenty feet further into this "void" resulted in damage to the drill bit apparently caused by high temperature. At year's end, the temperature regime in the cavity had not yet been established.

2. Based upon the apparent durability of the cavity and the qualitative indications regarding temperatures, it appears possible for a power measurement program to be undertaken to explore the possibility of recovering the heat released by the explosion. The lack of pressure in the cavity, which was apparently the result of the unplanned escape of steam, made pressure bleed-off unnecessary. The plan had been to introduce water to create the additional steam for the power experiment. The effect of the escape of steam on the temperature is not known.

3. With respect to experiments relating to the feasibility of recovering isotopes produced in a nuclear explosion, several approaches to the problems involved were being explored. Prompt recovery experiments were conducted by the Oak Ridge National Laboratory and the Livermore Laboratory using vacuum equipment on the surface to draw gaseous samples through a hole extending into the shot region. Analysis of the samples is presently underway. Study of filters and other substitute experimental techniques may provide information on certain other approaches which originally depended upon the regulated withdrawal of the steam created by the explosion. Additional approaches involve re-entry drilling and mining. One of the isotopes whose recovery was being studied was tritium. As pre-

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dicted, almost all the tritium was in the form of water vapor which suggests that isotopes present in gaseous phases may be easily recovered.

4. With respect to the basic research experiments being conducted by Los Alamos Scientific Laboratory and Lawrence Radiation Laboratory, the neutron wheels being used for the neutron physics experiments were recovered on December 16, 1961, and returned to the laboratories for examination. Both laboratories reported obtaining valuable data from their wheels. Basic chemistry experiments involved pre-shot placement of samples to study shock and pressure induced chemical changes and post-shot mining to recover the samples.

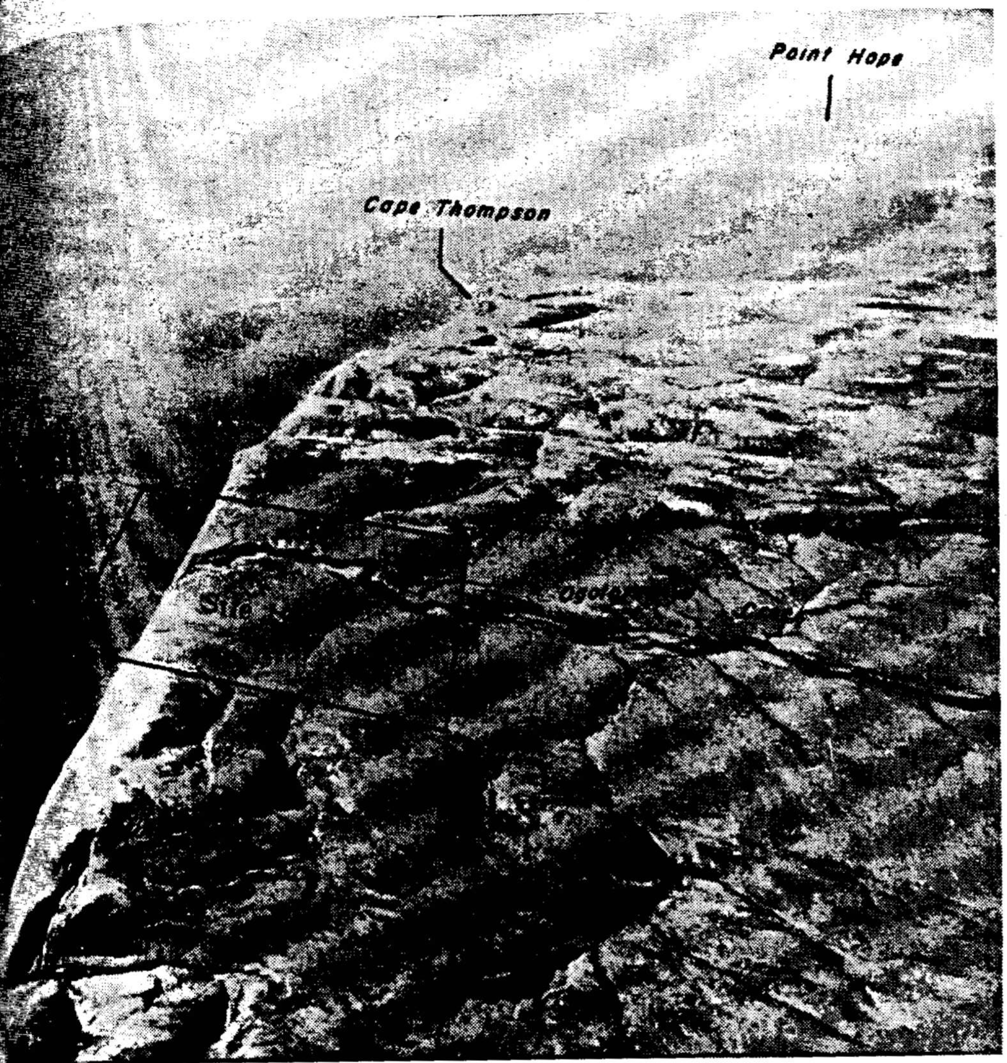
5. Physical effects studies are in progress and useful data have been and are being obtained. Extensive data in this area were being sought to extend knowledge of the characteristics of nuclear explosions to this new medium. Some instrument dependent results were lost, mainly due to cable damage. In connection with the physical effects of the detonation, it is interesting to note that the vertical shaft suffered no appreciable damage and is completely usable, and that the hoisting equipment is in excellent operating condition.

6. Data on the performance of the Plowshare device experiment was obtained and is being processed for analysis and evaluation. No information on the results of the experiment was available by the end of the year. If successfully proven, the design principles under study could lead to cheaper explosives with greatly reduced radioactivity. The device which was the energy source for the experiment and which had been adapted from an existing device, the design of which had previously been tested, provided sufficient yield for all experimental purposes.

Technical information developed in Project Gnome will be reported in the Commission's technical information system. Reports will become available for purchase from the Office of Technical Services, Department of Commerce, and will be placed in the Commission's depository libraries throughout the world.

An official observer program was conducted in two parts in connection with the Project. A tour of the underground facilities was conducted on November 26, 1961, with briefings on the preceding day. There were 197 official observers at the briefing, including sixteen from foreign countries; and 201 observers participated in the tour, including fourteen from foreign countries. As previously mentioned there were over 500 official observers present for the detonation. On December 9, a pre-detonation briefing was held, and a post-detonation briefing was held during the evening of December 10. Also there were a number of briefings conducted at the site during the day. In addition to the scientific and news media representatives of foreign

...ntries, there were representatives from Congress, the scientific com-...nity, industry, labor, organizations, federal, State and local govern-...nt, area residents, and the news media. Altogether sixteen foreign ...ions and two international organizations were represented.



...iot Site. Aerial view of the northern Alaska site under study for Project ...riot, a peaceful excavation experiment proposed for the Commission's Plow-...e program. The experiment, if conducted, would provide for the underground ...ation of four 20-kiloton and one 200-kiloton nuclear explosives which would ... a model-scale harbor within the area enclosed by the black lines on photo. ... purpose of the experiment would be to develop technology leading to the use ...uclear explosives in large-scale excavation work. To left of photo is the ...hi Sea, a part of the Bering Strait.

...ject Chariot

...entific investigations continued on Project *Chariot*, a peaceful ...ear excavation experiment under study for the Cape Thomp-... area in northwestern Alaska. No authorization has been given for

detonating nuclear explosives for this project, nor has any date for the proposed experiment been set. The proposal calls for simultaneously detonating underground, at depth of about 400 feet, four 20-kiloton nuclear explosives to excavate a ship channel, and one 200-kiloton nuclear explosive at about 800 feet to excavate a turning basin. Predicted dimensions for the channel are 900-feet wide, 200-feet maximum depth, and 2,000-feet long. The channel would connect the basin—1,800-feet in diameter and 400-feet maximum depth—with the ocean.

Intensive environmental studies[15] of the area surrounding the site have been made during the past several years by a team of scientists whose fields range from biology and human geography to geology, oceanography, and meteorology. These pre-detonation bioenvironmental studies continued through the report period. Safety and other aspects of the proposed project are still being evaluated. A determination of the feasibility of the proposed experiment will not be made until these studies and evaluations are completed.

The project is being planned by Lawrence Radiation Laboratory (Livermore), with field studies including teams from the University of Washington, the University of Alaska, the U.S. Fish and Wildlife Service, the U.S. Weather Bureau, the U.S. Public Health Service, the U.S. Geological Survey, the U.S. Army Corps of Engineers, and Commission staff and laboratory personnel.

Project Wagon

A low-yield nuclear cratering detonation for peaceful purposes is now being planned by the Commission's Livermore laboratory staff and would be conducted in a basalt formation at the Nevada Test Site. Called Project *Wagon*, it would yield important information for the application of nuclear explosives to excavation. Specifically, it would extend cratering experience to a new medium and provide information on the distribution of such radioactivity as may escape from the underground shot point. In addition, it would provide data on the critical relation between shot depth, size of crater, and possible escape of radioactivity.

[15] A summary of the first preliminary report on this environmental investigation appears in the appendix of the Commission's special report "Atomic Energy Research—Life and Physical Sciences, Reactor Development, Waste Management, 1961"; available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

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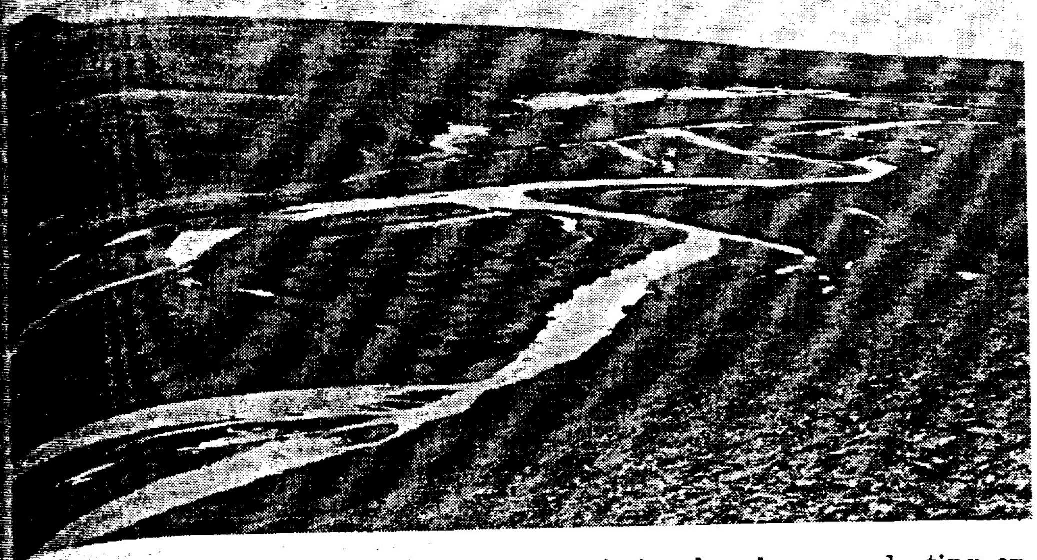

Chariot Studies. For several years the Commission has been conducting environmental investigations in the area of Alaska being studied as the site for Project Chariot. *Photo above* shows the lower reaches of Ogotoruk Creek, with the Chukchi Sea in the background, where the model-scale harbor would be created through nuclear explosives. *Photo below* shows two scientists from the Commission's Hanford, Wash., laboratories using a soil plug cutter to obtain samples of the insect life associated with different kinds of plants and soils in the proposed Project Chariot area. Such work is part of the overall environmental research being conducted to evaluate the effect such detonations would have on the ecology of the region.

Project Coach

Planning of a project called *Coach* is underway at the Livermore Laboratory. This project would basically be a scientific experiment and would involve the detonation of a specially designed, several kiloton nuclear explosive with high neutron flux to study: (*a*) the production of neutron-rich isotopes of known transplutonic elements, and (*b*) the possible production of elements heavier than those yet discovered. Data obtained from this experiment should contribute to the scientific theory underlying this area. Re-use of the Gnome site is being considered for this project. This project has not yet been authorized and no date has been set for it.

Chemical High Explosive Experiments

Several chemical high explosive (non-nuclear) projects have been conducted to advance the basic knowledge necessary for planning peaceful nuclear excavation projects and for developing a theory of cratering. Among these projects was the *Scooter* event in the fall of 1960, involving the detonation of 1,000,000 pounds of TNT buried at a depth of 125 feet in desert alluvium. This resulted in a crater 307 feet in diameter and 75-feet deep. These dimensions were within a few percent of pre-shot predictions which were based upon a new empirical scaling law evolved by scientists at Lawrence Radiation Laboratory (Livermore) and the Sandia Laboratory. Earlier cratering studies were Project *Buckboard*, conducted in basalt by Sandia, and Projects *Toboggan* by Sandia and *Rowboat* by Livermore, which were experiments in the Playa Lake Bed at NTS, with line charges.

Field Safety Studies

The environs of the *Teapot ESS* in 1955, and *Buster Jangle* in 1951, nuclear-cratering-effects tests at the Nevada Test Site are under study to determine the amounts and availability of various radionuclides, such as strontium 90. Soils, plants, and animals from the crater and crater lip are being sampled and analyzed. Similar studies are being conducted near the explosion sites of *Rainier* (1957), *Blanca* (1958), and *Logan* (1958). These latter events were underground nuclear weapons development tests.

Laboratory Programs

Besides the theoretical and engineering efforts required in support of the field program, several laboratory programs for peaceful pur-

have been undertaken by the Lawrence Radiation Laboratory (Livermore).

Theoretical Developments

A theory for the behavior of radioactivity released from nuclear-cratering explosions has been developed. Tests of the theory could be conducted in the planned *Wagon* experiment. A tentative theory of explosive crater production has also been developed and will be used in future projects.

Explosive Development

Special nuclear explosives which minimize the costs, radioactivity, and difficulties of installation are being developed for use in peaceful projects. Considerable progress in calculation and concept has been made.

Strong Shock Research

Many beneficial results of underground nuclear explosions are attributed to effects of the strong shock generated by the detonation. Laboratory investigations of strong shocks in solid materials have been undertaken. Currently under development, are facilities for generating appropriate shocks and instruments for measuring important shock parameters. Equations of state of shocked materials involved in various Plowshare applications are being measured. Also under study at the Livermore laboratory are chemical reactions and other molecular changes which occur under shock conditions. Strong-motion measurements are being studied by Sandia.

APPLICATIONS

Several detailed studies of specific peaceful applications are under way by Livermore. These studies are performed to determine economic and technical feasibility of the applications proposed for the Plowshare program, as well as to delineate safety considerations. They make use of the results of explosives and theory developments and provide criteria for additional theory and explosives research. Two studies—a model sea-level canal excavation by Sandia and an oil-shale experiment—have been completed. Three others; block-caving mining model, water-diversion canal model, and brine-disposal model, are in various stages of completion at Livermore.

FALLOUT STUDIES

Although responsibility for radiation surveillance and monitoring is assigned to the Department of Health, Education, and Welfare, several fallout sampling networks are operated for research purposes under partial or complete Commission sponsorship. These networks are shown in Table 5 as they were prior to Soviet resumption of nuclear weapons tests on September 1, 1961, and they have since been modified to obtain information on debris movement and deposition from those tests.

TABLE 5.—AEC-SUPPORTED SAMPLING NETWORKS FOR ATMOSPHERIC RADIOACTIVITY AND FALLOUT (Pre 9–1–61 and Post 9–1–61)

Type of sample	Sampling system	Scientific direction	Sample collection	Sample analysis	Number of locations		Samples per yr per station		Number of nuclides analyzed	
					Pre	Post	Pre	Post	Pre	Post
[illegible]per air	Balloon	WB*	AF	AEC & Contr.	1	1	60	60	3+	9+
			Australia	do	1	1	60	60	3+	9+
			Gen Mills Inc.	do	1	1	12	36	3+	9+
[illegible]per air	Aircraft	WB	AF	Various	4	4	60	60	8	8
[illegible]face air	80th Meridian	NRL	NRL & Coop.	NRL	14	14	52	365	1	1
[illegible]face air	AEC sites	AEC	Contr.				6	12	5	9
[illegible]face air	Special	Contr.	Contr.	Contr.	10	10	365	365	1	1
				Contr.	1	2	12	365	5	8
[illegible]position	Pot & funnel.	HASL	Coop.	HASL & Contr.	130	130	6	12	1	2
[illegible]position	Large-area	HASL & Contr.	Contr.	Contr.	7	7	50–150	50–150	2–5	3–8
[illegible]position	Gummed film.	HASL	Coop.	HASL	0	50	0	365	0	1
[illegible]	Soil	DA	DA & HASL.	HASL	167 (**)		1 (**)		1–2 (**)	
[illegible]	Sr-90	HASL	Coop.	HASL	2	2	12	12	1	2
[illegible]	Cs-137	LASL	LASL	LASL	16	16	52	52	2	2
[illegible]	Tri-City	HASL	HASL & Coop.	HASL	3	3	4	4	1	2
[illegible]	Consumers Union (CU).	CU	CU	CU	25	0	1	0	1+	0
[illegible]	Bone	HASL	HASL & Coop.	HASL & Contr.	4	4	100	100	1	1
[illegible]	Cs-137	LASL	LASL	LASL	variable				2	2

*WB—U.S. Weather Bureau.
NRL—Naval Research Laboratory.
AEC—Atomic Energy Commission.
HASL—AEC Health and Safety Laboratory.
Contr.—AEC Contractor.
DA—Department of Agriculture.
LASL—Los Alamos Scientific Laboratory.
**The need for continuation of this program is under study.

In general, the complete analysis of samples generated by these networks requires weeks or months. The resulting data, while not useful for rapid surveillance, do contribute to the assessment and prediction of longer-term exposures and as soon as they are obtained from the responsible scientists are reported to the Department of Health, Education, and Welfare, Public Health Service for publication in their monthly *Radiological Health Data*

These networks have provided much of the experimental evidence now available regarding the atmospheric residence time for nuclear weapons debris, and how this varies with the altitude, latitude, and yield of the detonation. In particular, unique radioactive isotopes of tungsten and rhodium have been used to identify Operation HARDTACK (test series in 1958 at Eniwetok Proving Ground and Nevada Test Site) surface-burst debris and ORANGE shot high-altitude debris respectively.[25]

Based on data from these programs and from other sources, an inventory and material balance of all the strontium-90 produced in tests prior to November 1958 have been estimated by U.S. Weather Bureau scientists. As of December 1960, the estimates are as follows:

ESTIMATED STRONTIUM 90 INVENTORY

(megacuries)

Total produced in tests prior to November 1958	9.2
Corrected for decay to December 1960	8.1
Less ⅓ local fallout	−2.7
Total available for worldwide fallout	5.4
Deposition based on mid-1959 soil measurements (corrected for decay to December 1960)	4.0
Deposition, mid-1959 to December 1960 based on pot and funnel measurements	0.7
Total worldwide deposition, December 1960	4.7
Stratospheric inventory based on aircraft and balloon measurements, December 1960	1.0
Total accounted for by air and ground measurements, December 1960	5.7

NOTE.—The estimated uncertainty in each of the above figures is at least 20 percent, so that the difference between the total available and the total accounted for is well within the error of measurement.

[25] Results of these studies and other aspects of the fallout studies program are reported in "Atomic Energy Research—Life and Physical Sciences, Reactor Development, and Waste Management—1961", available from Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.